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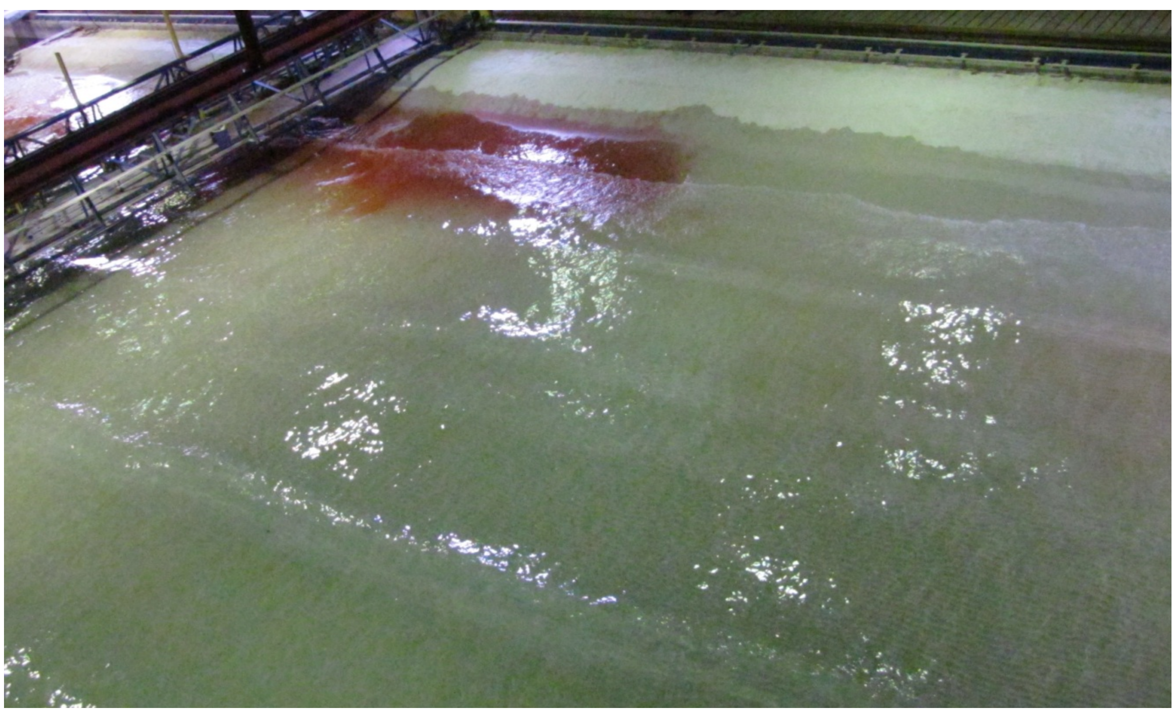
Modeling of Nearshore-Placed Dredged Material

Ernest R. Smith, Rusty Permenter, Michael C. Mohr, and Shanon A. Chader

July 2015



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Abstract

Movable-bed, large-scale laboratory experiments were conducted at a 1:20 scale to examine the fate and quantify the performance of nearshore-placed dredged material as subaerial and submerged mounds or berms. Three tests were performed for mounds placed at depths representing 1.2 and 3.35 meters and placement onshore. Mound sand was dyed to provide contrast and to differentiate it from the natural sand beach used in the model. Beach surveys were performed intermittently during each 9-hour (prototype) experiment with a laser scanner. In addition to beach change elevations, the scanner provided RGB color components, which enabled tracking of the mound sand. Mound sand dispersed rapidly and was transported mainly downdrift. However, no evidence of appreciable accretion was observed downdrift of the mounds placed offshore. Although the mound sand was transported downdrift, sand accumulation was observed on the beach onshore and updrift of the mounds. Beach response was similar to that of an offshore breakwater in which the mound provides a wave shadow zone to the leeward beach. The mound placed on the foreshore slope accreted in the swash zone directly downdrift of the mound and near the shoreline over the beach length. The experiment demonstrated that nearshore-placed material remains in the surf zone and adds material to the beach face.

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Preface

This study was conducted for the U.S. Army Engineer District, Buffalo (LRB), the U.S. Army Corps of Engineers (USACE) Dredging Operations and Environmental Research (DOER) Program, and the USACE Regional Sediment Management (RSM) Program.

The RSM Program is administered at the U.S. Army Engineer Research and Development Center (ERDC), Coastal and Hydraulics Laboratory (CHL), under the USACE Navigation Research, Development, and Technology Transfer (RD&T) Program. At the time this effort was conducted, Jeffrey A. McKee was the Headquarters USACE Navigation Business Line Manager overseeing the RSM Program. W. Jeff Lillycrop, CHL, was the ERDC Technical Director for Civil Works and Navigation RD&T. Charles E. Wiggins, CHL, was the USACE Associate Technical Director for Navigation.

This report was prepared by Dr. Ernest R. Smith and Rusty L. Permenter, Coastal Processes Branch (CEERD-HF-C), Flood and Storm Protection Division (CEERD-HF), CHL; and Shanon A. Chader and Michael C. Mohr (LRB).

Experiments in a physical model laboratory at CHL were performed between April 2011 and August 2011 and were conducted by Dr. Smith, Permenter, and William K. Halford (CEERD-HF-C); and Raymond Reed, Harbors, Entrances, and Structures Branch (CEERD-HN-H). Tim Nisley, ERDC Information Technology Laboratory (ITL), provided instrumentation support.

This study was conducted under the general administrative supervision of José E. Sánchez, Director, CHL; Mark Gravens, Chief, CEERD-HF-C; Dr. Ty Wamsley, Chief, CEERD-HF; Craig Forgette (LRB), Great Lakes Regional Sediment Management Program Manager; Dr. Joseph Z. Gailani (CEERD-HF-C), Sediment and Dredging Processes (SDP) Focus Area leader of DOER; Dr. Todd S. Bridges (CEERD-EM-D), USACE DOER Program Manager; and Linda S. Lillycrop, CHL, USACE, RSM Program Manager.

At the time of publication of this report, LTC John T. Tucker III was Acting Commander of ERDC. Dr. Jeffery P. Holland was the ERDC Director.

1 Introduction

The U.S. Army Corps of Engineers (USACE) continues to seek opportunities for the beneficial use of dredged material. Frequently, USACE dredged-material management plans include offshore placement of dredged material from channel entrances and ebb shoals. This often removes material with a high sand percentage from the littoral or regional system. Depending on region, maintenance dredged material from these areas is not always considered beach quality (>88% sand) but may include a relatively large percentage of sand (e.g., approximately 60%–80% sand).

One strategy for reducing dredging impacts to regional coastal systems is the nearshore placement of dredged material where the sand is placed in several meters of water depth, beyond the calm weather surf zone but within the littoral region. Waves then act as the agent to winnow the fines and facilitate onshore sand transport towards the beach. Benefits of additional sand placed in shallower water include reduced need for beach nourishment, conserved capacity of offshore dredged material placement sites, and enhanced nearshore beach profiles.

While the benefits of preserving the sand and using waves for beach-face placement are obvious, there is no consensus on the effectiveness of this concept, especially considering the possible increased cost of nearshore placement. Optimal placement and the mechanism of onshore sand migration are largely unknown. Nearshore mound locations, material, and configurations must be chosen judiciously to assure that the mound does not negatively impact the surrounding environment and that material remains in the littoral system and nourishes the beach.

The focus of the present study is to examine the design for nearshore placement of dredged material through laboratory data. The USACE District, Buffalo (LRB), and the Engineer and Research Development Center (ERDC) Coastal and Hydraulics Laboratory (CHL) performed movable-bed physical model experiments to assist in evaluating the fate and to help quantify the benefits of nearshore sand placement. Three nearshore mound locations, two submerged offshore and one placed on the foreshore slope, were subjected to waves in a three-dimensional (3D) basin. The resulting bathymetry was measured with detailed surveys to

determine the benefits of nearshore-placed sand to the shoreline and beach. Additionally, data obtained from the laboratory study were provided to substantiate a specialized numerical model, C2SHORE, and implement numerical modeling technology to calculate the fate of sand placed in the nearshore (Johnson and Smith 2012).

In this report, the facility, design, and construction of the laboratory experiments are described in Chapter 2, laboratory results are presented in Chapter 3, and a summary of the study is given in Chapter 4. Appendix A includes beach bathymetry contour plots, and Appendix B contains bathymetry difference plots.

2 The Physical Model

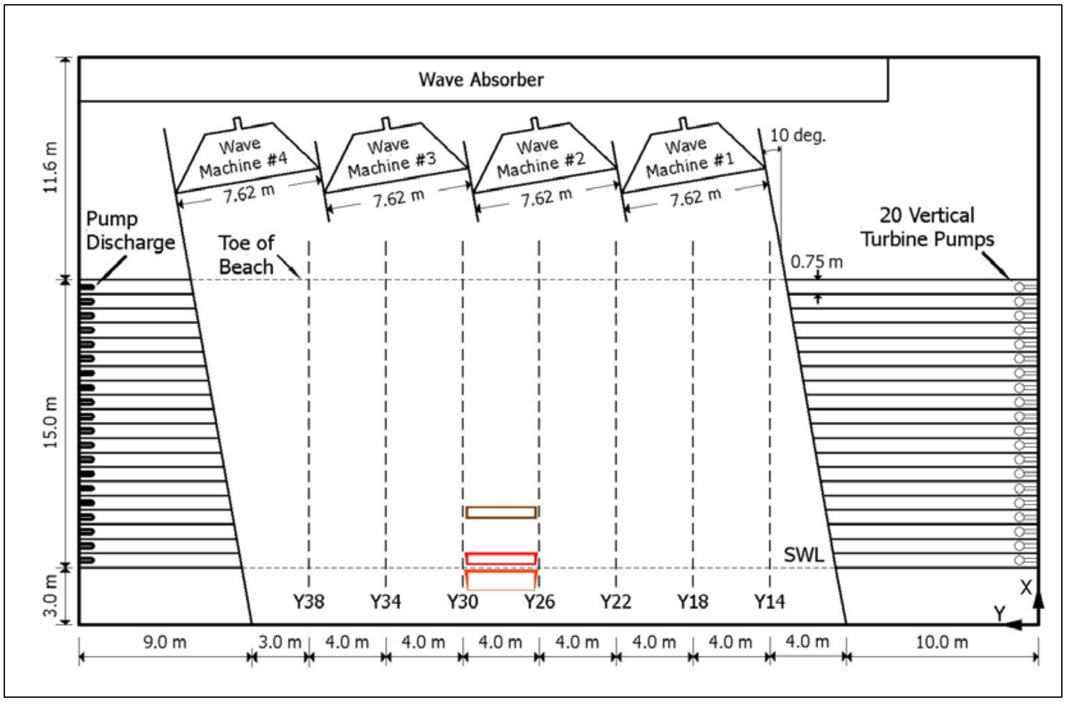
Physical model experiments were conducted in the CHL Large-Scale Sediment Transport Facility (LSTF). ERDC constructed the LSTF in an effort to overcome the limitations of small-scale facilities and to bridge the gap between field and previous laboratory measurements. The intent for the facility is to reproduce certain surf-zone processes found on a long, straight natural beach in a finite-length wave basin. The LSTF simulates nearshore hydrodynamic and sediment transport processes at a relatively large geometric scale, including situations where considerable sand is mobilized and transported in suspension. Detailed design considerations, capabilities, and initial testing of the LSTF are described in Hamilton et al. (2001). This chapter describes the LSTF and its instrumentation, physical model design, study conditions, and procedures.

2.1 The Large-Scale Sediment Transport Facility (LSTF)

The LSTF consists of a 30-meter (m) wide, 50 m long, 1.4 m deep basin (Figure 1) and includes wave generators, a sand beach, a recirculation system, sand traps, and an instrumentation bridge. The origin for the LSTF coordinate system is the corner of the two basin walls shown in the lower right of Figure 1. Hence, positive “X” is offshore and positive “Y” is to the left. Also shown in the figure are the locations of the three mounds examined in the study between Y=26 and 30.

The LSTF is equipped with four wave generators operated simultaneously. Each generator has a board length of 7.62 m and is synchronized with the other generators to produce 30.5 m, unidirectional, long-crested waves. A digitally controlled drive servo electric system controls the position of the piston-type wave board and produces waves with the periodic motion of the board. The system allows a variety of regular and irregular wave types to be produced. The generators were positioned at 10 degrees (deg) from shore normal for the present experiment. A Texel-Marsen-Arsloe (TMA) shallow-water wave spectrum (Bouws et al. 1985) with a gamma value of 3.3 was used to define the spectral shape for the wave condition in the present study.

Figure 1. LSTF plan view and mound locations where the brown line is Mound 1 (3.35 m depth), the red line is Mound 2 (1.2 m depth), and the orange line is Mound 3 (onshore).

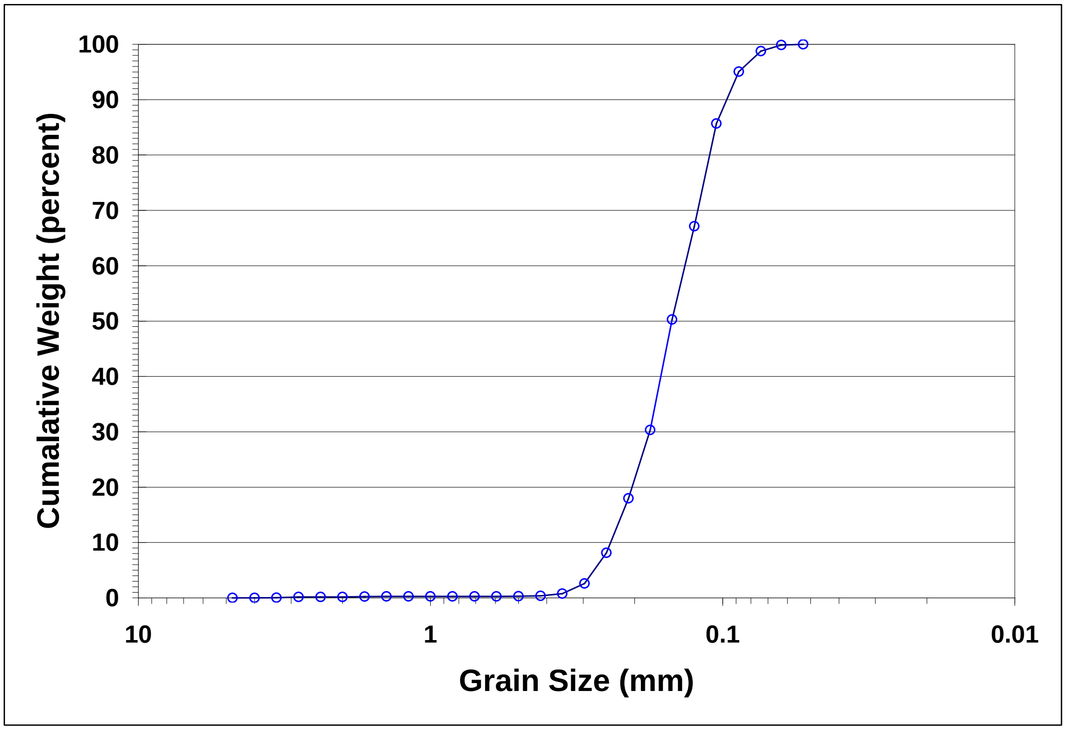


The sand beach consists of approximately 150 m^3 of fine quartz sand having a mean grain diameter, d_{50}, of 0.15 millimeters (mm) with a narrow distribution (Figure 2). The lateral boundaries of the beach were bounded by stacked 19.5-centimeter (cm) long by 9 cm wide mortar bricks having heights ranging from 1.4 to 5.6 cm. The use of bricks of varying height allowed flexibility in constructing the boundaries similar to the average beach profile. Additionally, because of their density, they are less likely to be displaced under waves and currents than other materials.

The model beach is of finite length and bounded at the upstream and downstream ends. To minimize adverse laboratory effects created by the boundaries and to produce uniform longshore currents across the beach, wave-driven currents are supplemented by an external recirculation system discussed by Hamilton et al. (2001), Hamilton and Ebersole (2001), and Visser (1991). The recirculation system consisted of 20 independent vertical turbine pumps placed in the cross-shore direction at the downdrift boundary. Flow channels placed upstream of each pump are used to direct flow to the pump, which externally recirculates water to the upstream end of the facility where it is discharged through flow channels onto the beach. The objective of this system is to maximize the length of beach over which waves and wave-driven longshore currents are uniform by continually

recirculating currents of the same magnitude as the wave-driven longshore current through the lateral boundaries of the facility. Each pump includes a variable speed motor to control discharge rates. The variable speed motors are controlled remotely to produce a cross-shore distribution of longshore current. Without the external circulation system, the longshore current would be forced to circulate within the test basin, which would introduce basin effects and contaminate the wave-generated currents.

Figure 2. Grain-size distribution of LSTF sand.



The facility includes a 21 m instrumentation bridge that spans the entire cross-shore length of the beach. The bridge serves as a rigid platform to mount instruments and observe experiments. Each end of the bridge is independently driven on support rails by drive motors, which allows it to travel the entire alongshore length of the wave basin. The bridge can be positioned by the control computer to any desired alongshore location.

2.2 Instrumentation

2.2.1 Wave measurements

Time-series of water surface elevations were measured using single-wire, capacitance-type wave gauges. Ten gauges mounted on the instrumentation bridge provided wave height measurements as the waves transformed from

offshore to nearshore. The cross-shore location of the gauges can be repositioned on the bridge. In addition to the bridge-mounted gauges, a gauge was placed in front of wave generators 1 through 3 to measure offshore wave characteristics

Calibration of the wave gauges was performed prior to the experiment. Calibration was computer controlled and involved raising and lowering each rod to 11 known elevations at which voltages were recorded. A least-square fit of measurements using 21 voltage samples per gauge minimized the errors of slack in the gear drives and hysteresis in the sensors. Typical calibration errors were less than 1% of full scale for the capacitance wave gauges.

2.2.2 Current measurements

Ten acoustic Doppler velocimeters (ADVs) (Kraus et al. 1994) were deployed to measure orbital wave velocities and unidirectional longshore current. The ADVs were positioned at the same cross-shore position on the bridge as the wave gauges but separated by approximately 40 cm in the longshore direction to prevent electrical interference between the two instruments. As with the wave gauges, the ADV cross-shore location can be repositioned on the bridge and were adjusted according to mound location. The ADVs were positioned vertically to sample at a location that gives the average velocity in the water column (an elevation equal to one-third of the water depth from the bottom [Hamilton et al. 2001]).

2.2.3 Survey method

High-resolution beach surveys were obtained with a 3D scanning laser, which has a horizontal and vertical accuracy of 0.3 mm for the LSTF. The scanner produced bathymetric data as a point cloud between alongshore locations Y14 and Y36 (Figure 1). The data were interpolated to a grid with cross-shore spacing of 0.005 m and longshore spacing of 0.2 m, which allowed direct bathymetric comparisons between surveys. Use of the laser scanner required a dry profile; therefore, it was necessary to lower the water to a level that exposed the portion of the beach to survey. It was essential to lower water slowly to prevent erosion of the sand bed from draining water.

In addition to location and elevations, the laser scanner through the use of a camera attachment, collected red, green, and blue (RGB) color components

at each elevation in the point cloud. Dyed mound sand provides good contrast with the white *native* sand, and the contrast can be distinguished in the survey data. Therefore, the mound sand remaining on the surface can be tracked through time and Cartesian space. Each bathymetric survey was analyzed through image processing to obtain the locations of the dyed mound sand to compare with beach change elevations.

2.2.4 Sediment traps

Eighteen sediment traps were installed in the downdrift flow channels of the LSTF to collect sand transported through the downdrift boundary. Two additional traps were located landward of the first flow channel to quantify the longshore sediment transport rate near the still-water shoreline and in the swash zone. Each sand trap was equipped with three load cells to weigh the amount of trapped sand, allowing the cross-shore distribution of longshore sediment transport to be determined.

Because the total amount of longshore sediment transport during individual wave runs was only a small fraction, less than 1%, of the total amount of sand on the artificial beach, continuous sand recharging during wave runs was not necessary (Hamilton et al. 2001). The traps were emptied at the conclusion of a mound test, and the material was placed back onto the beach. After the traps were emptied, the beach was rebuilt to uniform contours.

The downdrift traps consisted of rectangular aluminum boxes sealed to the flow channels and the test beach with rubber neoprene and a certain amount of sand deposits on the rubber seal. Generally, the total quantity that accumulates on all rubber seals is 3% to 12% of the total that actually settles into the trap. However, the percentage of sand accumulating on the seals can approach 15% to 20% in individual traps. To account for this error, accumulated sand was washed off the rubber seals into the individual traps following each test segment and incorporated in the total measured sand weight.

2.3 Physical model design

Model experiments were conducted at a geometrically undistorted linear scale, which was based on the capabilities of the available wave generator to produce required wave heights at modeled water depths. Time relations were scaled according to Froude Model Law (Stevens et al. 1942) and model-prototype relations were defined in terms of length, l, and time, t, listed in Table 1.

Table 1. Model-prototype scale relations (1:20 scale).

Characteristic	Dimension	Scale Relations Model:Prototype
Length	l	lr = 1:20
Area	l 2	ar = 1:400
Volume	l 3	vr = 1:8,000
Time	l 1/2	tr = 1:4.47

Selection of the design wave condition requires knowledge of the associated, reproducible distribution of longshore currents. It is necessary to pump currents at the lateral boundaries that match the wave-driven longshore currents in the LSTF. The wave-driven currents are a function of the incident wave condition and the cross-shore wave height distribution, which adjusts as the beach profile evolves. Matching the pumped currents to wave-driven currents requires an iteration process of setting the pumps, measuring velocities on the beach at several longshore locations, adjusting the pumps to the measurements, and repeating until the pumped and wave-driven currents are similar. This process can be lengthy and is dependent on the time the beach profile reaches a quasi-equilibrium condition.

Four wave height and period conditions have been performed in the LSTF in which the distribution of longshore currents has been established (Smith et al. 2009). One of these conditions, referred to as Test 5, is a wave having a peak period, T_p, of 1.5 seconds (s) and wave height, H_{mo}, at the wave maker of 0.18 m. From Table 1, the condition translates to a 6.7 s, 3.6 m wave at the 18 m water depth at a 1:20 scale. This wave condition was suitable for conducting the nearshore mound experiments and wouldn't require iteration of the longshore currents. Therefore, the initial profile, wave conditions, and pumped longshore currents of Test 5 were used for the present study. Wave height distribution and the beach profile is shown in Figure 3 at model scale in which waves approach from the right. Longshore current distribution is given in Figure 4 for model scale in cm/s on the left ordinate and in prototype scale in m/s on the right ordinate.

The representative prototype sand size was calculated by similitude of the relative fall-speed criterion as discussed by Dean (1973) and the Hallermeier (1981) method to calculate fall speed. At a 1:20 scale, the LSTF sand represents a d_{50} of 0.54 mm.

Figure 3. Wave-height distribution and bathymetry for the mound tests.

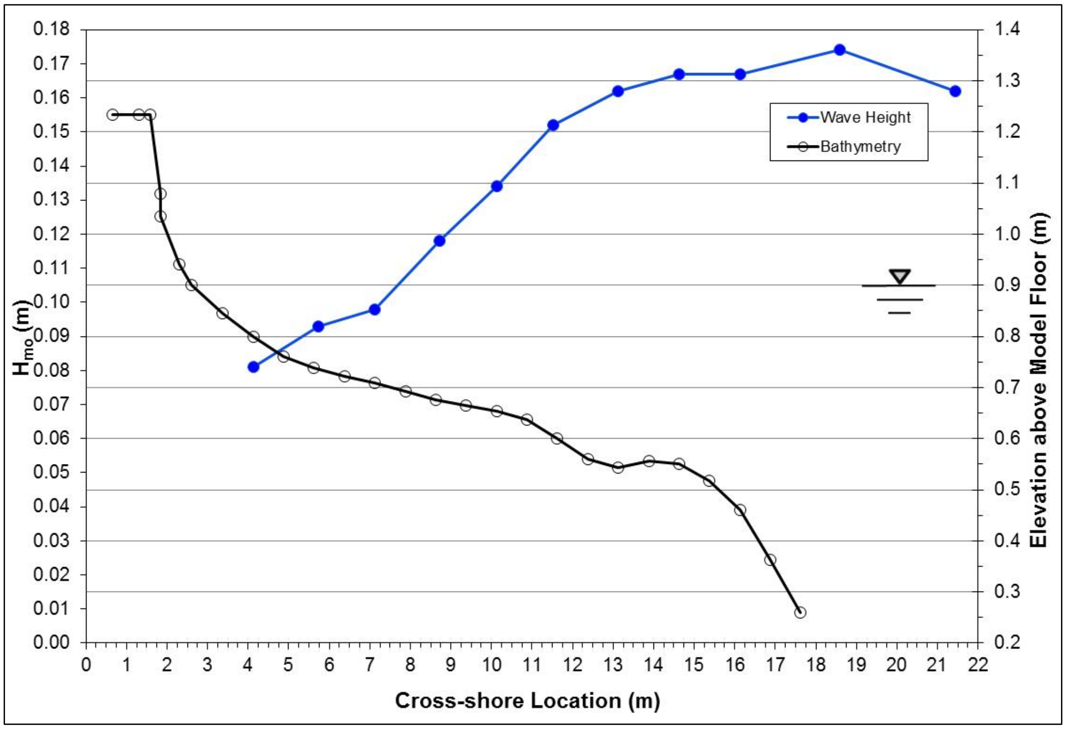
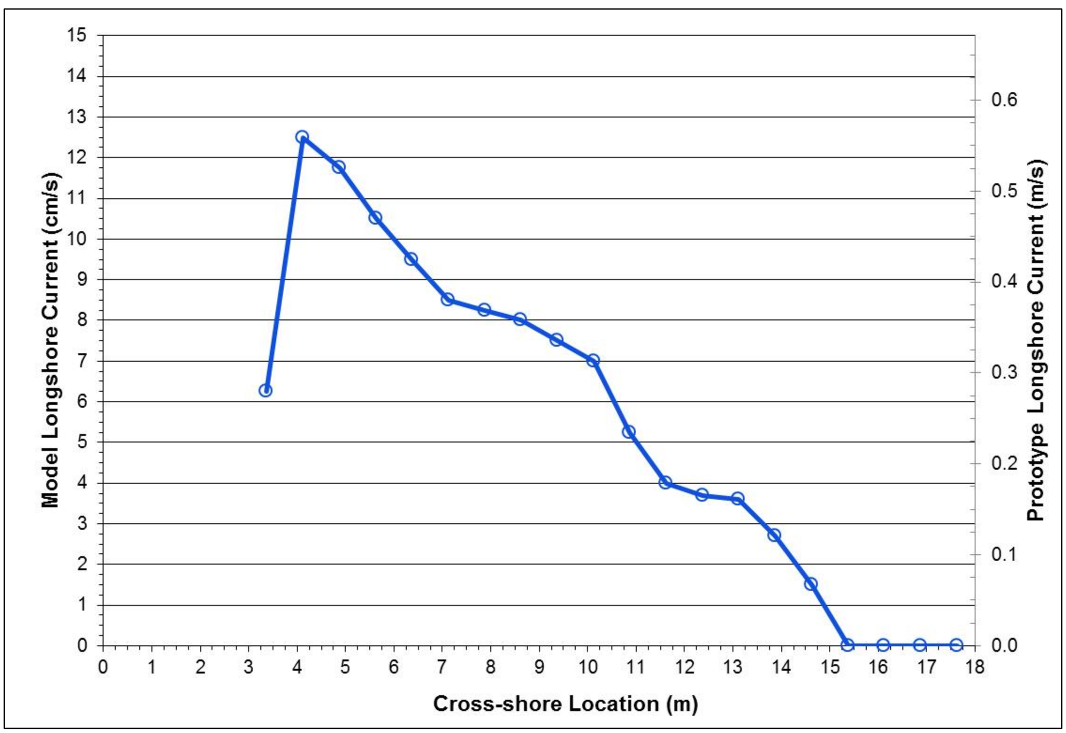


Figure 4. Longshore current distribution for mound test wave condition.



2.4 Test procedures

2.4.1 Mound sand dyeing method

Sand used in each of the mounds tested was dyed to provide contrast against the white native sand of the LSTF. Sand was mixed with liquid cement color until all sand was of uniform color. The sand was allowed to air dry and was subsequently baked in an oven between 70 and 80 °C for a minimum of 24 hours (hr). After removal from the oven, the sand was suitable to be placed on the beach for testing. During initial waves, some coloring was observed to disperse from the mound. It is suspected that the dispersed color was excess dye and very fine material mixed with the sand that was released upon wave agitation.

2.4.2 Beach construction

The same procedure was followed for all tests in the present study. The beach was constructed to the profile shown in Figure 3, beginning at the onshore end and working offshore. The bridge includes openings to place stainless steel rods every meter in the cross-shore direction. The rods were used as a guide to help maintain straight and parallel contours. Moving the bridge along the facility left traces in the sand at the desired beach elevation and indicated locations that required cutting or filling. A tractor was used to cut the beach to an approximate grade. Boards were placed in the cross-shore direction on the beach at the elevations indicated by the rods and attached to the bridge. The boards were used to grade and smooth the sand with the bridge’s movement. The bridge does not have the capability to handle loads required to cut into the beach; therefore, the boards were used to grade the beach only where fill was required. The beach could be graded alongshore at approximately 2 m cross-shore intervals by this method. Each 2 m segment of graded beach was compacted with the tractor at least once and regraded before moving the boards offshore.

The mound was built after beach construction had progressed to the offshore portion of the specific cross-shore mound location. Placement of the mound in the alongshore direction was based on LSTF locations that are not affected by the boundaries. The LSTF beach between alongshore locations Y = 18 m and Y = 30 m remains relatively uniform and is not affected by the boundaries. Therefore, all mounds were constructed within the uniform region of the LSTF. The mound was constructed at the updrift end of the uniform region to provide adequate distance from the downdrift

boundary to observe transport of mound sand. The mound was constructed by laying out the outer dimensions with bricks and filled with the dyed sand (Figures 5 and 6). The boards used to grade the beach were set to the mound elevation, and the bridge was moved to create a level surface. The mound crest dimensions were measured, and slopes tied the mound base to the crest. The bricks were removed (Figure 7), any dyed sand on the native LSTF beach was removed, and the offshore portion of the beach was constructed.

2.4.3 Data collection procedure

Following beach construction, the beach was surveyed with the laser scanner and photographed from several positions. The basin was filled to 0.9 m, and a pre-test sample of the traps was taken. The recirculation pumps were started, and a video camera placed directly above the mound was set to record. The bridge was positioned at the desired location, and waves were produced. Waves were generated for 5 minutes (min) to allow the model to achieve its operational state before collecting wave and current data for 5 or 10 min. After data had been collected at the location, the bridge was either moved to its next data collection position or the wave generators and pumps were stopped to conclude the test segment. A post-test sample of the traps was taken, although it should be noted that this sample did not include the sand that resided on the trap rubber seals. The post-test sample was taken as the pre-test sample of the following test segment. Sand on the trap rubber seals was washed into the traps and a final sample was taken at the conclusion of a mound configuration.

The mound sand was transported predominately downdrift of the mound. At the conclusion of a mound configuration test, sample cores were taken at six to eight alongshore locations aligned with the intial mound cross-shore location to observe depth of mixing of the mound sand. The sand in the traps was then emptied and placed back on the beach, and the beach was constructed for the next mound configuration.

Figure 5. Construction of Mound 2.

Figure 6. Construction of Mound 2.

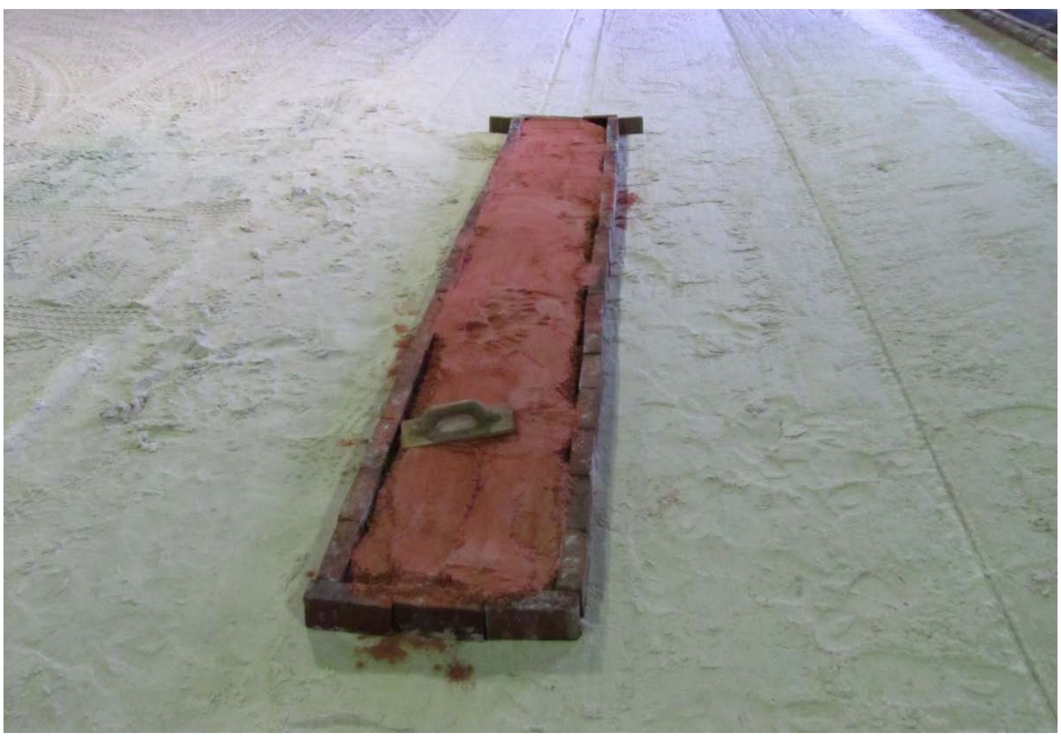
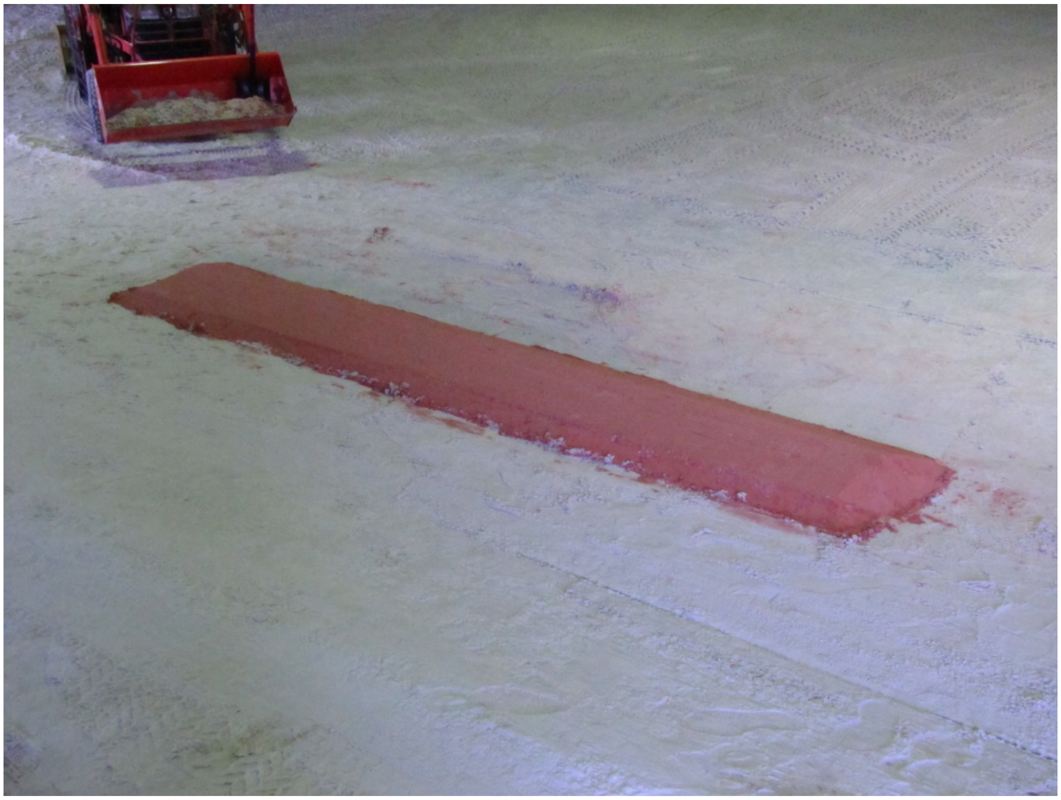


Figure 7. Mound 2 after construction.



3 Physical Model Results

The Test 5 beach profile constructed for the study was near equilibrium. However, it was difficult to construct the foreshore slope to equilibrium where elevation change was great and included curvature. The beach was constructed by assuming uniform slopes between elevations at 1 m cross-shore intervals, and the bathymetry in this area could differ with the equilibrium profile. The beach adjusted to any deviations between the constructed and equilibrium profile when the beach was subjected to wave action. These changes were independent of mound presence. One of the objectives of the study was to determine profile and volume change with time due to the additional sand from the mounds. Changes as a result of mound placement would be difficult to discern if the beach profile also was evolving. Therefore, in addition to the three mound placement tests, a base condition was added in which the beach was constructed without a mound. The base condition was subjected to the same duration test segments as tests with mounds. Beach change comparisons between mound test segments were first made by comparing the mound and base condition test segments at common times. These differences were then compared to differences between the initial and base condition beaches. This method reduces errors due to changes in the beach profile.

The mounds dispersed rapidly, and the majority of sand was transported from the mound within the first 30 min of wave action. The standard data collection duration in the LSTF is 10 min; however, one of the objectives of the study was to monitor beach change. Including time to bring the LSTF to operational state, the minimum test segment would be 15 min, which would allow only one opportunity to survey the beach while sand remained in the mound. For the present study, the data collection time was reduced to 5 min, which reduced the minimum test segment time to 10 min and allowed for an additional stop to survey the beach as the mound was eroding. Five minutes of data with a 1.5 s peak period provided measurements of approximately 200 waves, which was sufficient for analysis. Beach change slowed as the test progressed, and very little change occurred after 120 min. Therefore, data collection time was increased to 10 min for test segments beyond 30 min, and the total duration for each test was 120 min. Surveys were performed on the initial beach and after 10, 20, 30, 60, and 120 min of wave action.

It was important to observe and collect video of sand transported from the mound. The instrument bridge was positioned to collect data updrift or downdrift of the mound during initial test segments to allow an unobstructed view of the mound. Transects at which data were collected followed the sequence in Table 2. The table lists the test segment, transect, and approximate time of data collection.

Table 2. Alongshore data collection sequence.

Test Segment	Y (m)	Approximate Start Time (cumulative min)
1	22	5
2	20	15
3	30	25
4	18	35
4	22	45
5	30	65
5	28	75
5	26	85
5	24	95
5	22	105

This chapter describes results from the physical model study. Included in this chapter are wave height distribution plots and selected contour and difference plots for each test. All beach contour plots are presented in Appendix A, and all difference plots are shown in Appendix B.

3.1 Base Condition

The initial Base Condition beach bathymetry is shown in Figure 8, where the contour lines show beach elevation measured from the model floor in meters (water level of each test was at 0.9 m). Although some irregularities are present, the contours are generally straight and parallel in the longshore direction. A panoramic photo of the initial beach is shown in Figure 9.

The average cross-shore profile of the Base Condition is plotted in Figure 10 with the equilibrium profile of LSTF Test 5 (Smith et al. 2009). Although the profiles are similar, there are discrepancies between profiles. A scarp formed with the Test 5 profile, and it was not desired to reconstruct a scarp face in the present study. Therefore, a milder foreshore slope was constructed for the present study. The Test 5 shoreline was located at

Y ≈ 2.6 m, and it was preferred to match the shoreline and foreshore slope of the equilibrium profile. As a result of the construction method, the Base Condition beach was 2 cm lower near the 3 m cross-shore location. Two areas were built higher than the Test 5 beach. The Base Condition beach was constructed approximately 1 cm higher between 6 and 9 m, and 2 cm higher between 11 and 14 m. The Base Condition survey extended to 16 m but indicates that the offshore slope is steeper than the Test 5 slope.

Figure 8. Base Condition initial beach bathymetry.

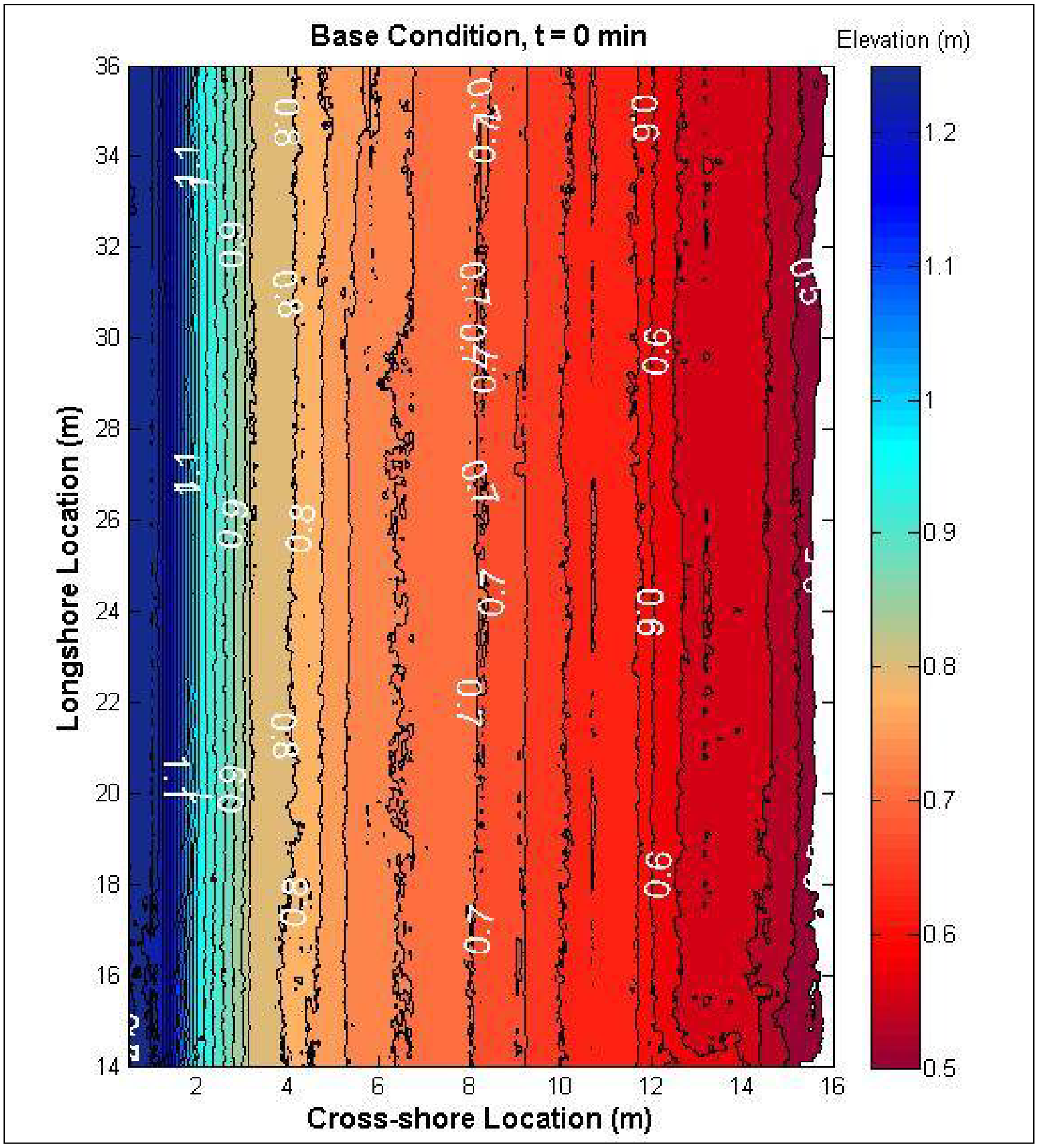


Figure 9. Panoramic view of the Base Condition initial beach.

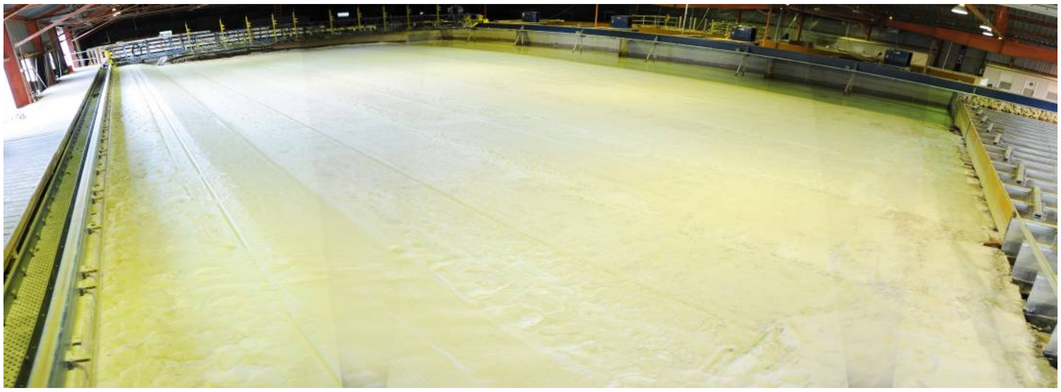


Figure 10. Average beach profile of Base Condition initial beach and Test 5 beach.

Bathymetry after 120 min of waves is given in Figure 11. The final bathymetry shows variability in the contours but generally uniform between Y = 18 and 30 m. A photo of the final beach is shown in Figure 12. The photo shows ripples over most of the beach in both the longshore and cross-shore directions. The longshore-directed ripples are caused by the waves, and the cross-shore ripples, which are more visible in the photo, result from the longshore current. The swash zone is absent of ripples.

Figure 11. Base Condition bathymetry after 120 min.

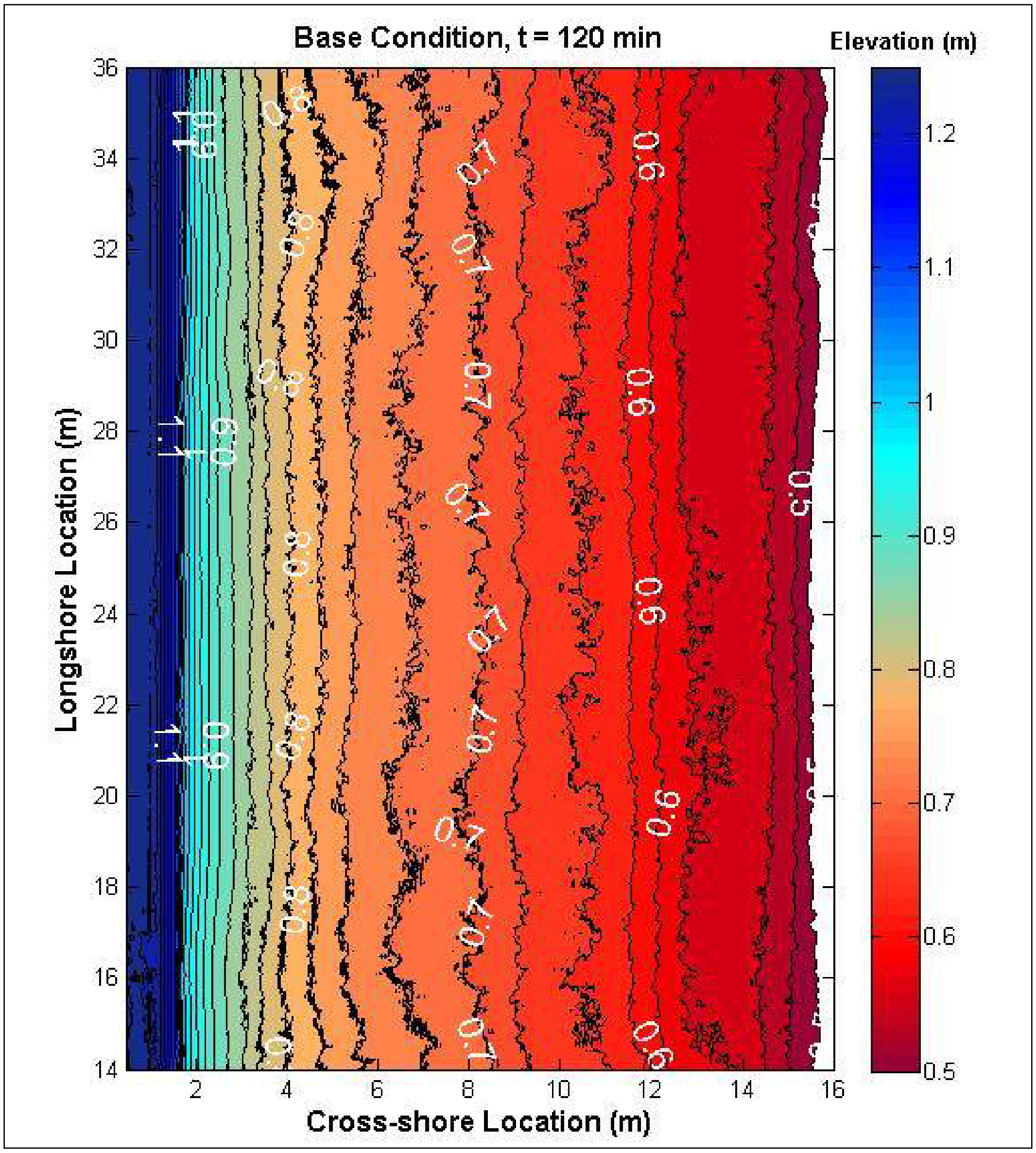
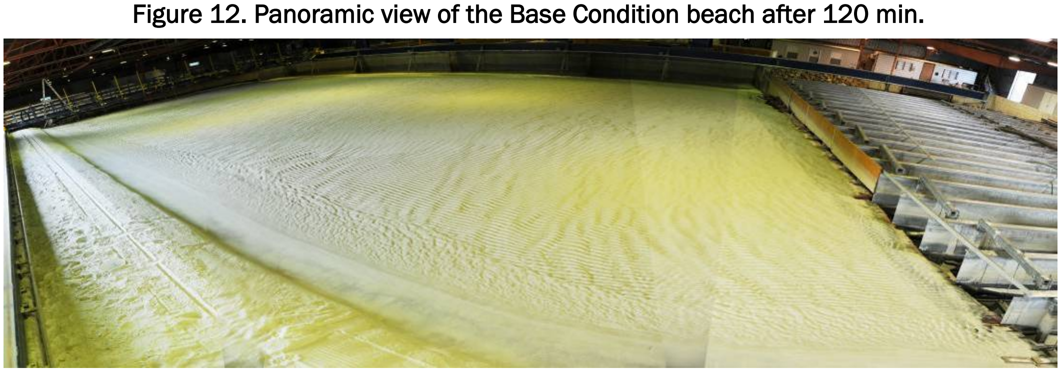


Figure 12. Panoramic view of the Base Condition beach after 120 min.



Elevation differences between the final test segment and initial beach are shown in Figure 13. Elevations of the Base Condition beach were slightly lower than the Test 5 beach near X = 3 m, and the accumulation observed near that location reflects that the beach is evolving to the Test 5 profile. The scarp of the Test 5 beach was not desired, and the foreshore slope constructed eliminated the formation of a scarp. However, Figure 13 indicates the slope is eroding to a milder slope than that constructed. Isolated areas of erosion and accretion are apparent throughout the beach. Note that the beach was constructed with a planar alongshore bottom, and ripples formed immediately when subjected to waves. Some of the isolated bathymetric changes can be attributed to ripple formation.

Figure 13. Base Condition bathymetry difference after 120 min of waves.

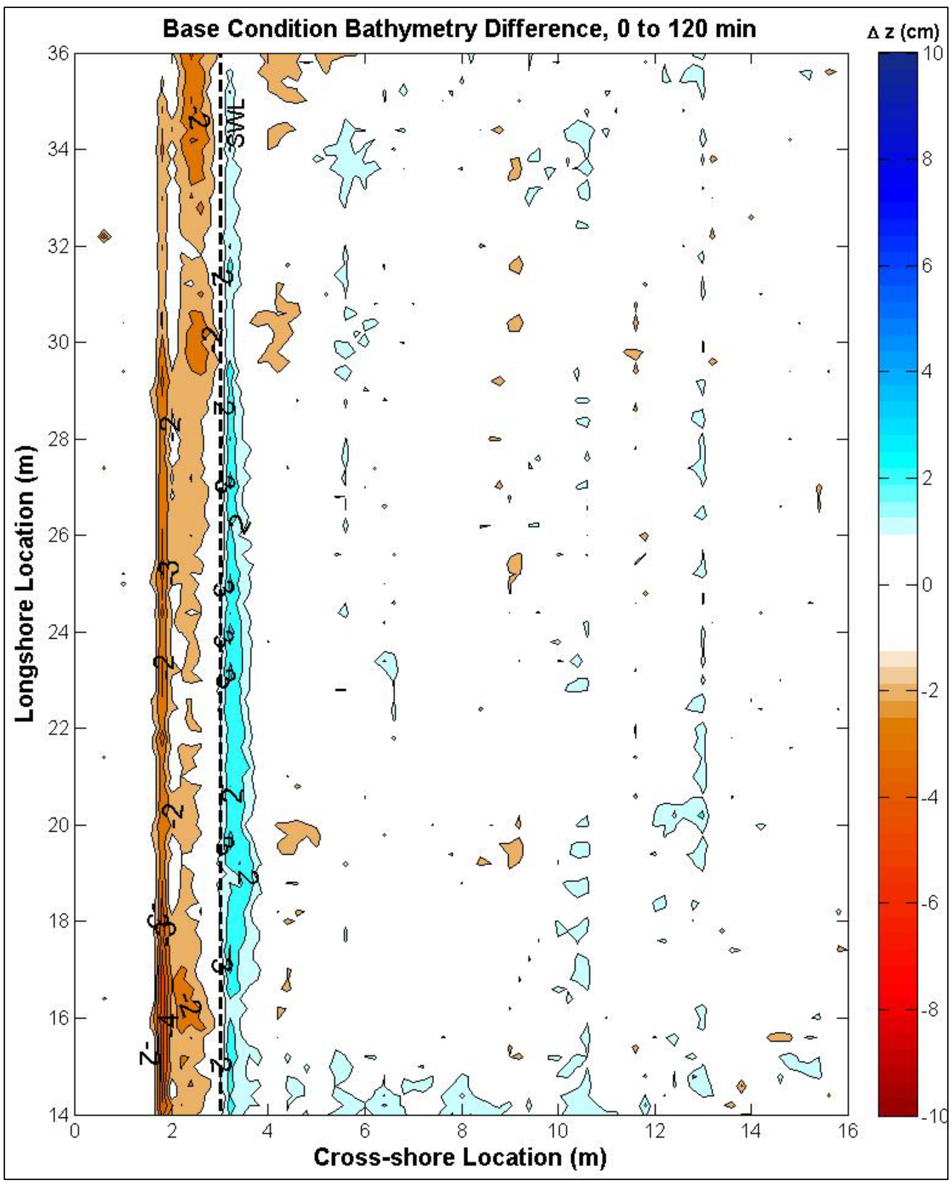
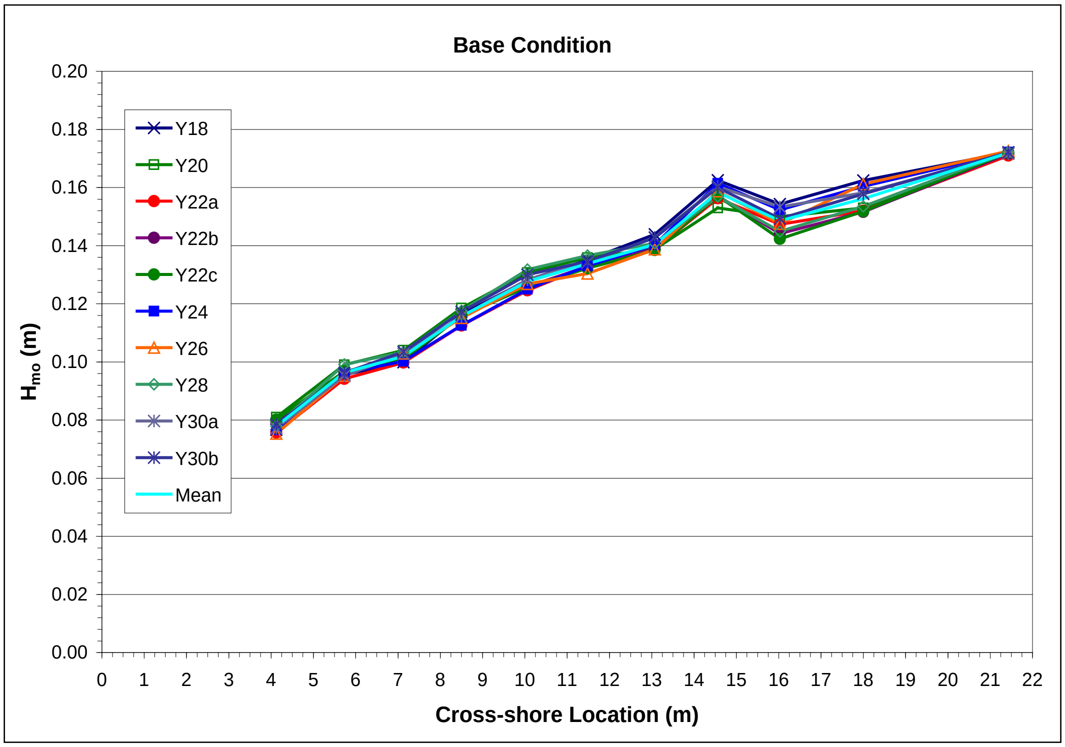


Figure 14 shows the cross-shore distribution of wave heights at all measured transects for the Base Condition. The figure shows wave heights decrease between the generator and beach, with some variability, and shoal prior to breaking at X = 14.5 m. A sharp decrease in height occurs immediately shoreward of the breakpoint followed by milder dissipation. The alongshore distribution of wave heights is nearly uniform in the surf zone.

Figure 14. Cross-shore distribution of wave height for the Base Condition.



3.2 Mound 1[1]

Mound 1 was constructed between Y = 26 m and Y = 29 m at a model scale depth of 0.17 m below still water level (swl) with 0.10 m^3 (3.4 ft^3) of sand dyed brown. Prototype values at a 1:20 scale represent a 3.4 m depth and 800 m^3 (28,300 ft^3) volume. The cross-sectional profile of Mound 1 at Y = 28 m, the mound centerline, is shown in Figure 15. Also shown is the profile of the Base Condition and the Mound 1 profile at Y = 22 m. The Mound 1 profile matches the Base Condition well but is slightly lower shoreward of the mound. Mound 1 initial bathymetry is plotted in Figure 16. The profile at Y = 22 m (Figure 15) and parallel contours shown in the initial bathymetry plot (Figure 16) illustrates that the beach was

[1] English units are included to express mound volumes in this section.

uniformly lower than the Base Condition shoreward of the mound. Panoramic photos of the Mound 1 initial beach are shown in Figures 17 and 18, and a photo of the mound looking offshore is shown in Figure 19.

Waves were generated for a total of 120 min. Unfortunately, the hard drive containing the survey data acquired after the final test segment failed. Bathymetry following 60 min of wave action is shown in Figure 20. The figure shows the diminished mound outlines and shows that the mound sand has spread. Contours remain uniform. Photographs of the Mound 1 beach after 60 min are shown in Figures 21 through 23. The photographs show the brown mound sand had dispersed and transported predominantly downdrift. Also, a scarp began to form at the limit of wave uprush (Figure 21). Photographs taken after 120 min (Figures 24 to 26) show the brown sand to be lighter in color and in less area, indicating the mound sand continued to be transported downdrift and mixed with the native sand.

Figure 15. Mound 1 initial beach profile at locations Y=22 and 28 m.

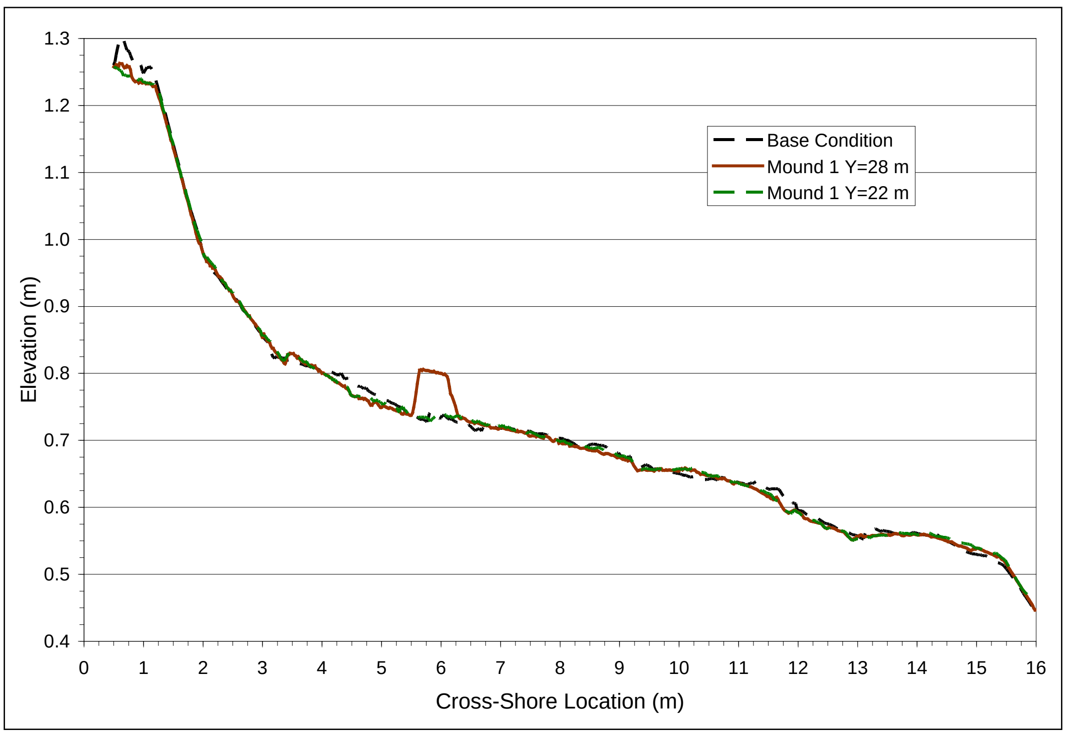


Figure 16. Mound 1 initial bathymetry.

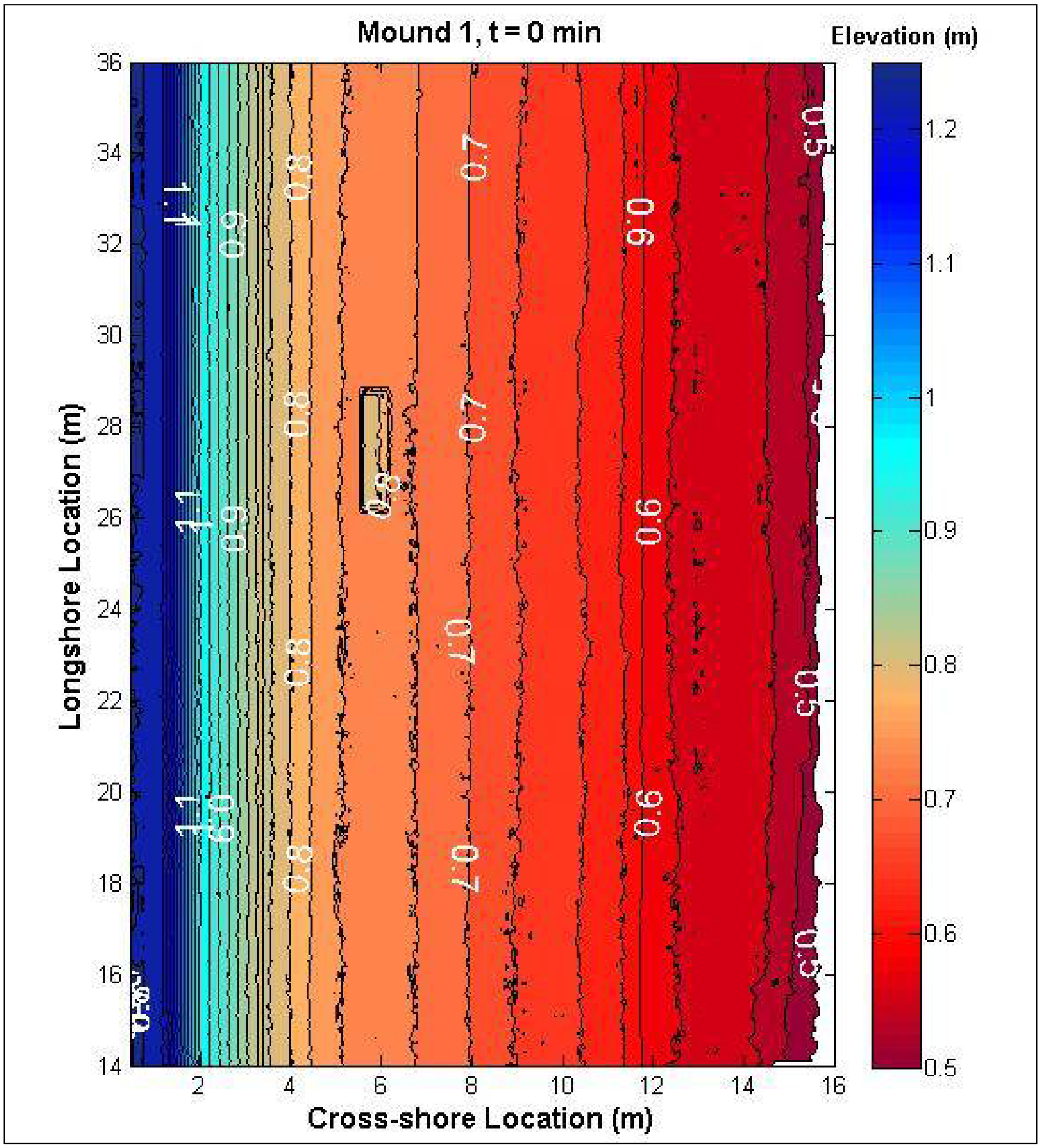


Figure 17. Panoramic view of the Mound 1 initial beach looking updrift.

Figure 18. Panoramic view of the Mound 1 initial beach looking downdrift.

Figure 19. Mound 1 initial beach looking offshore.

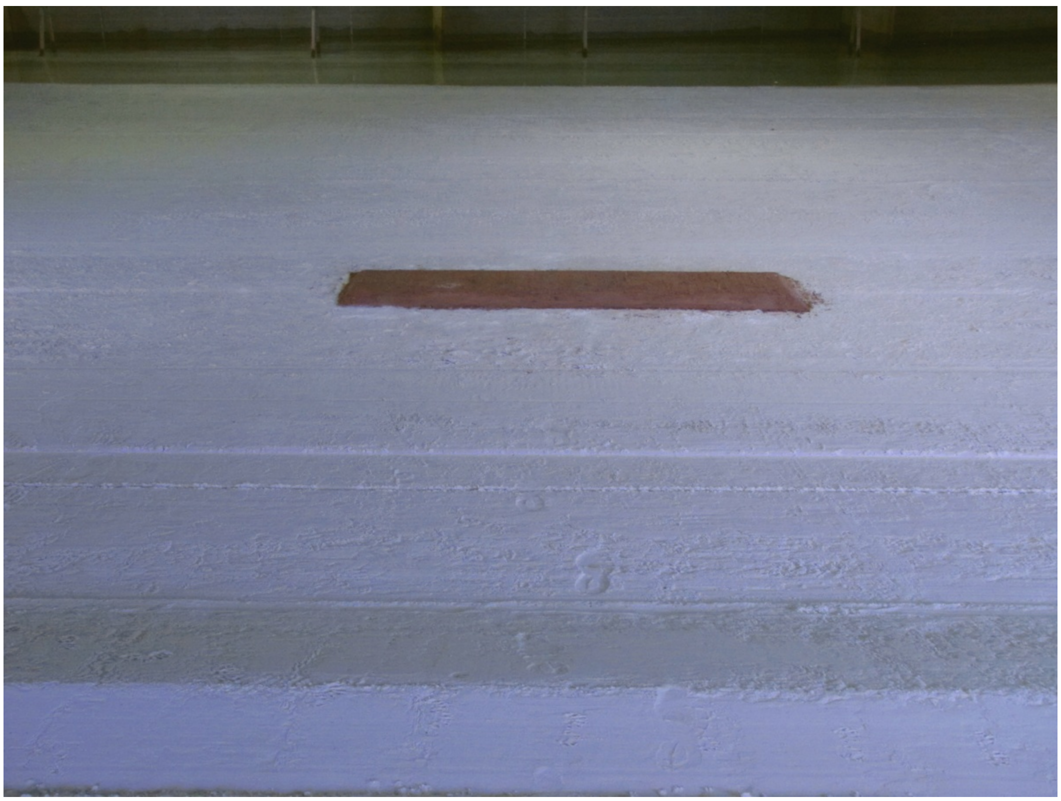


Figure 20. Mound 1 after 60 min of waves.

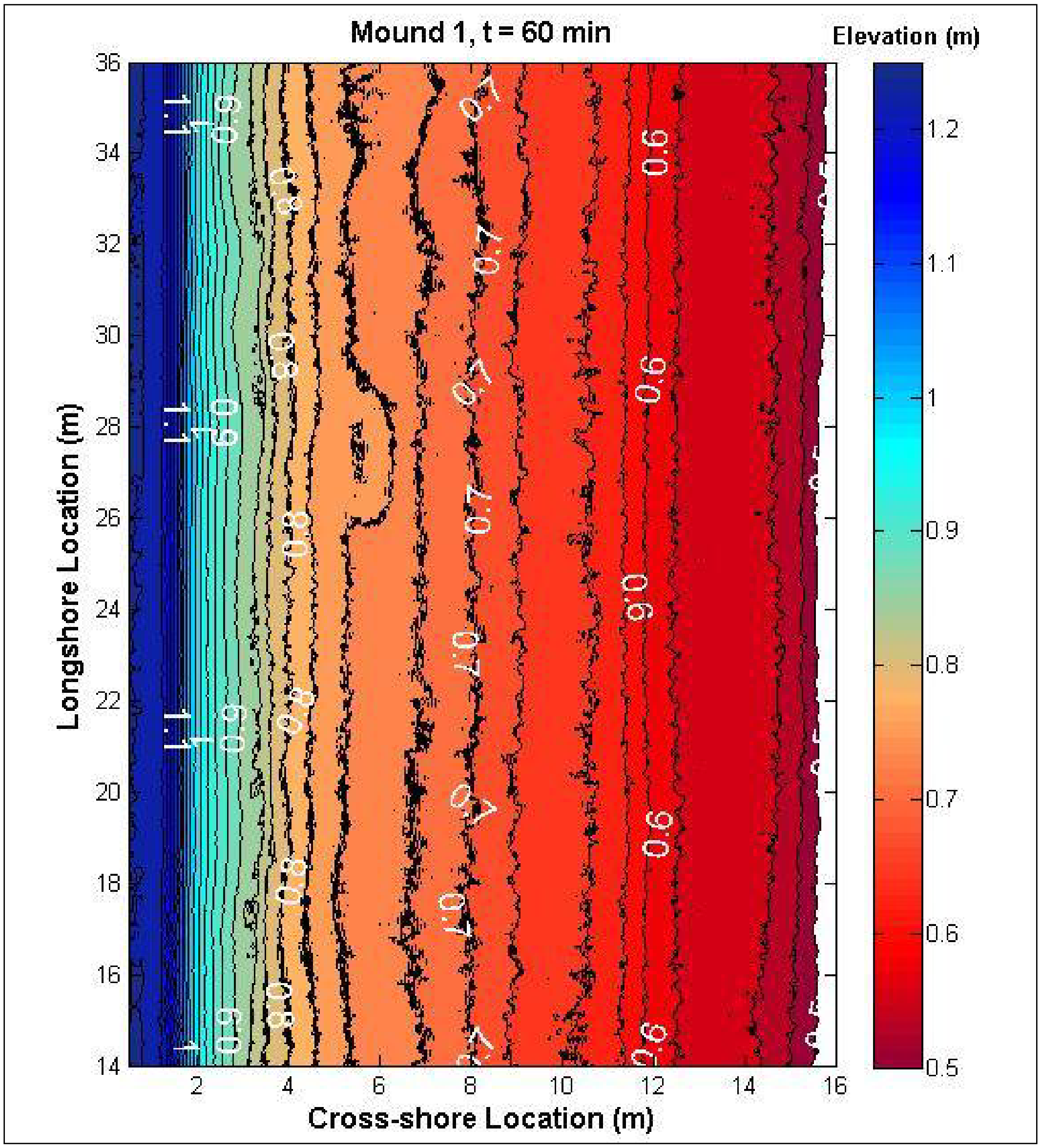


Figure 21. Panoramic view of the Mound 1 beach looking updrift after 60 min of waves.

Figure 22. Panoramic view of the Mound 1 beach looking downdrift after 60 min of waves.

Figure 23. Mound 1 beach looking offshore after 60 min of waves.

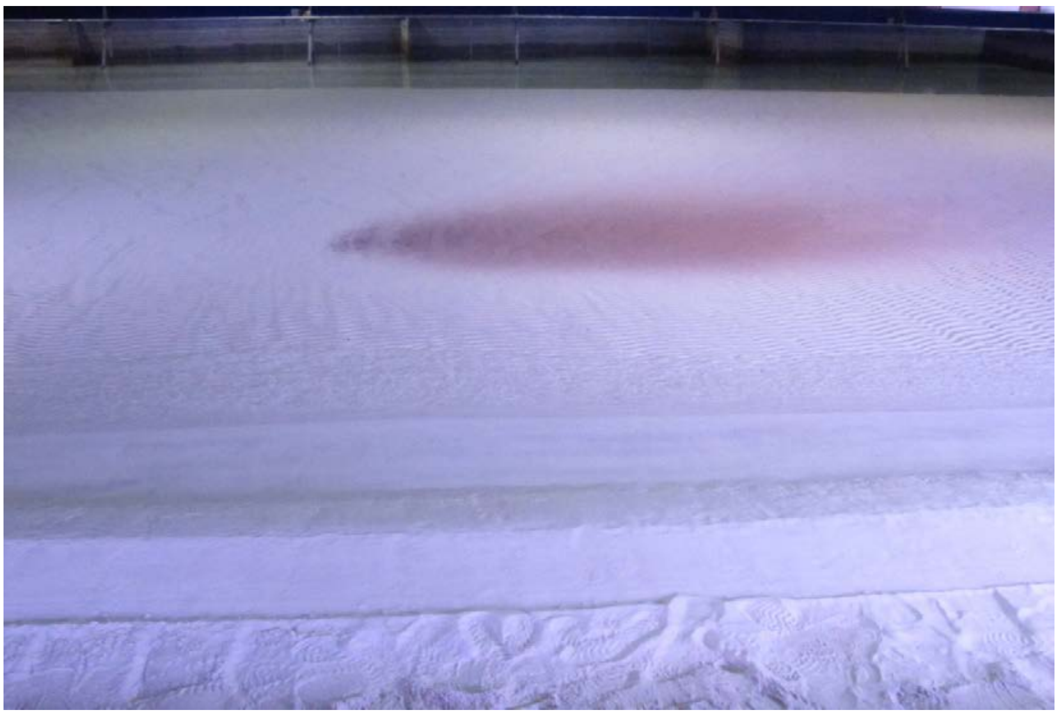


Figure 24. Panoramic view of the Mound 1 beach looking updrift after 120 min of waves.

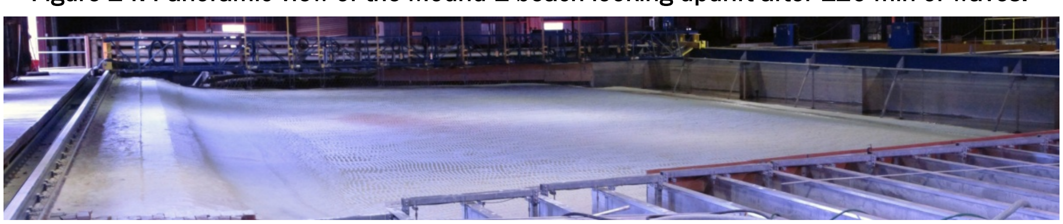


Figure 25. Panoramic view of the Mound 1 beach looking downdrift after 120 min of waves.

Figure 26. Mound 1 beach looking offshore after 120 min of waves.

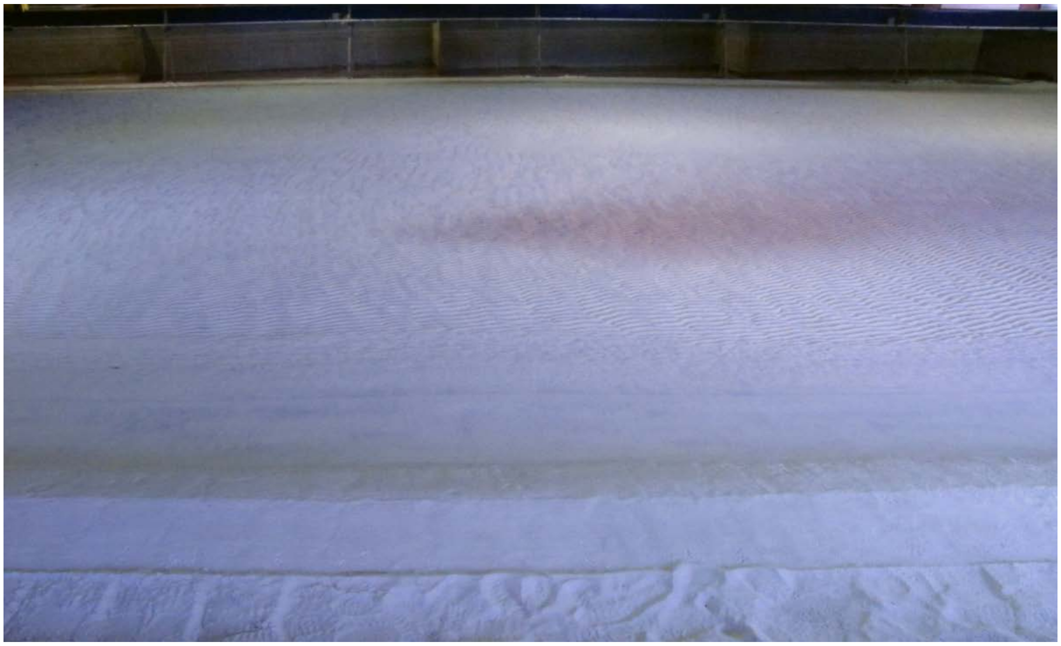


Figure 27 shows sand samples taken with 10.8 cm long tubes at the cross-shore centerline of the mound at alongshore locations of (left to right) Y = 34, 30, 28, 26, 24, 22, 20, and 18 m. As expected, the samples show more mound sand present near the original mound location with lesser amounts evident farther from the original placement. However, the photos show that the mound sand is mixed with the native LSTF sand at Y = 24 m to a depth of 0.6 cm. Little mound sand is visible at Y = 30 m, directly updrift of the mound, and no mound sand is apparent at Y = 34.

Figure 27. Photograph of Mound 1 sand samples collected after 120 min of waves at alongshore locations (from left to right): Y34, Y30, Y28 Y26, Y24, Y22, Y20, and Y18.

Elevation differences between the 60 min test segment and initial beach is shown in Figure 28 in which the shaded gray area indicates the area covered by the dyed mound sand obtained from image processing of the laser scanner data and the dashed line indicates the swl shoreline. Although the figure shows mound sand transported downdrift of the mound, no appreciable accretion is apparent within the shaded area of mound sand. Accretion is observed directly onshore and updrift of the mound. The Mound 1 profile in Figure 15 showed that the beach was constructed at a slightly lower elevation than the Base Condition template shoreward of the mound. Alongshore changes in bathymetry due to differences in construction of this test versus the Base Condition template beach are negligible in this area, and the shoreward accretion observed is a result of the sheltering effect of the mound.

The original placement of the mound is apparent in Figure 28 where much of the mound sand was eroded. Bathymetry changes downdrift of Y16 and between Y34 and Y36 are a result of proximity to the downdrift and updrift boundaries, respectively. A line of erosion is apparent onshore and downdrift of the mound. The morphologic response of the beach is similar to that of an offshore breakwater in which the mound, although depleted of sand, shelters the beach from waves onshore of its location. Longshore transport is disrupted with accretion occurring updrift and erosion downdrift. Figure 28 indicates that sand is trapped onshore of the mound, accreting the beach. Downdrift of the influence of the mound, sand is transported alongshore resulting in erosion.

Figure 29 shows the cross-shore distribution of wave heights with Mound 1 and the mean heights with the Base Condition. Waves propagating over Mound 1 have more longshore variability than observed with the Base Condition (Figure 14), and breaking occurs farther offshore. Additionally, dissipation in the surf zone is not as uniform as with the base condition; dissipation is milder between X = 11.5 to 10 m, at which heights decay more sharply, which may indicate a secondary break point. Wave heights at the innermost gauge are lower at the two longshore locations nearest and downdrift of the mound, Y26 and Y28.

Observations from photographs indicate that the majority of mound sand moved downdrift of the mound placement. However, differences in surveys also show accumulation onshore of the mound, which may have been caused by sheltering effects of the initial mound. Some sand appeared to move offshore of the mound but remained in the surf zone.

Figure 28. Mound 1 relative bathymetry difference after 60 min of waves.

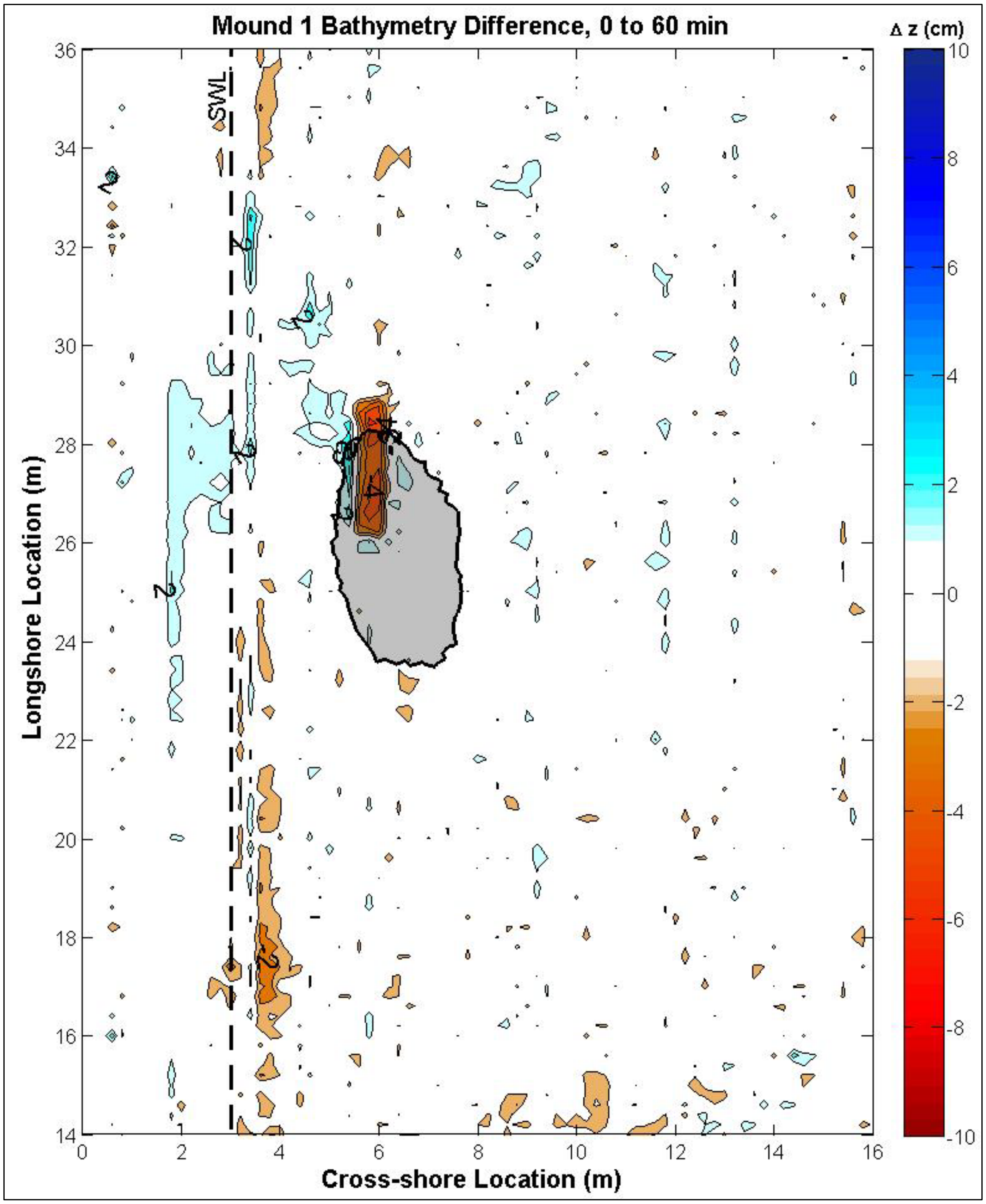
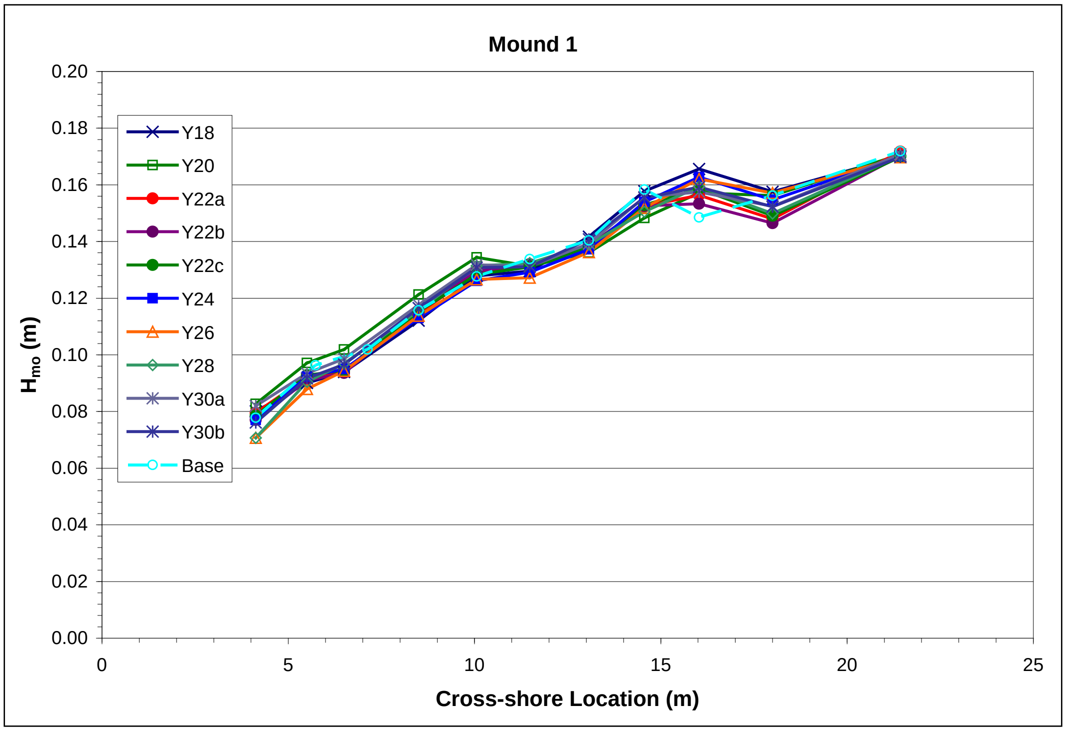


Figure 29. Cross-shore distribution of wave height for Mound 1.



3.3 Mound 2

Mound 2 was constructed between Y = 26 and Y = 30 m at a model scale depth of 0.06 m below swl to represent a prototype depth of 1.2 m. The mound was built 1 m longer than Mound 1 with 0.17 m^3 (5.9 ft^3) of sand (dyed red), which represented 1,330 m^3 (47,000 ft^3) at a 1:20 scale. The cross-sectional profile of Mound 2 at the mound centerline (Y28) is shown in Figure 30 with the profile of the Base Condition and the Mound 2 profile at Y = 22 m. The Mound 2 and Base Condition profiles are similar, but the mound profile deviates from the base profile offshore, particularly between X = 11 and approximately 12 m. Mound 2 initial bathymetry is plotted in Figure 31 and photos of the initial beach are shown in Figures 32 to 34.

Mound 2 bathymetry measured after 120 min is shown in Figure 35. No evidence of the mound is apparent from the bathymetric plot. Photographs of the Mound 2 beach after 120 min are shown in Figure 36 through 38. The figures show that the mound has completely dispersed and the red mound sand has transported from the original placement to the downdrift boundary. A small scarp is shown to develop at the upper limit of wave runup (Figure 36). Sand samples taken at the cross-shore centerline of the mound are shown in Figure 39 for alongshore locations of (left to right) Y = 34, 30, 28, 26, 22, and 18 m. Red (mound) sand is not apparent at

Y = 34 m but is present in all other samples, and the red sand has mixed with the native sand into the bed to depths ranging from 2.3 to 3.8 cm. The photographs and samples indicate sand from Mound 2 was transported alongshore farther than sand from Mound 1. The greater transport distance is related to the higher longshore currents at the Mound 2 cross-shore location than at the Mound 1 location.

Elevation differences between the final Mound 2 test segment and initial beach are shown in Figure 40. Similarly to Mound 1 tests, accretion had occurred onshore of the mound. Accretion also is apparent in the area surrounding the placement vicinity, especially directly updrift of the placement location. Figure 40 shows that the dyed mound sand was transported from the original placement to the downdrift boundary with no significant onshore accretion resulting from the mound sand transport.

Figure 30. Mound 2 initial beach profile compared to the Base Condition profile.

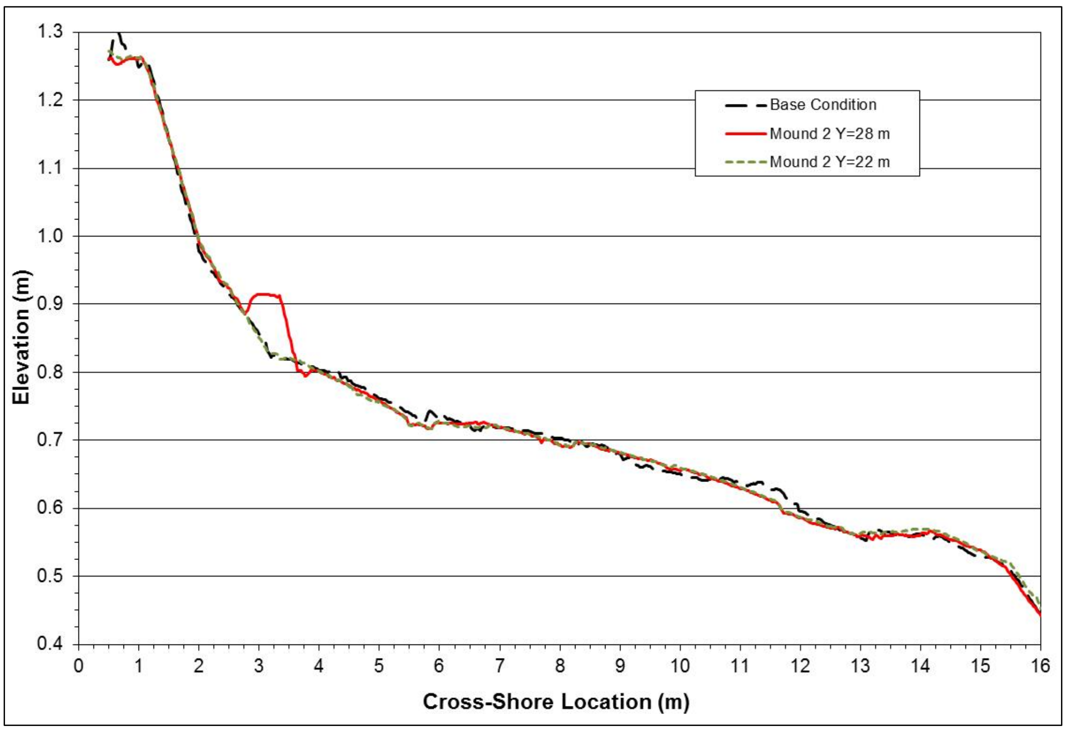


Figure 31. Mound 2 initial bathymetry.

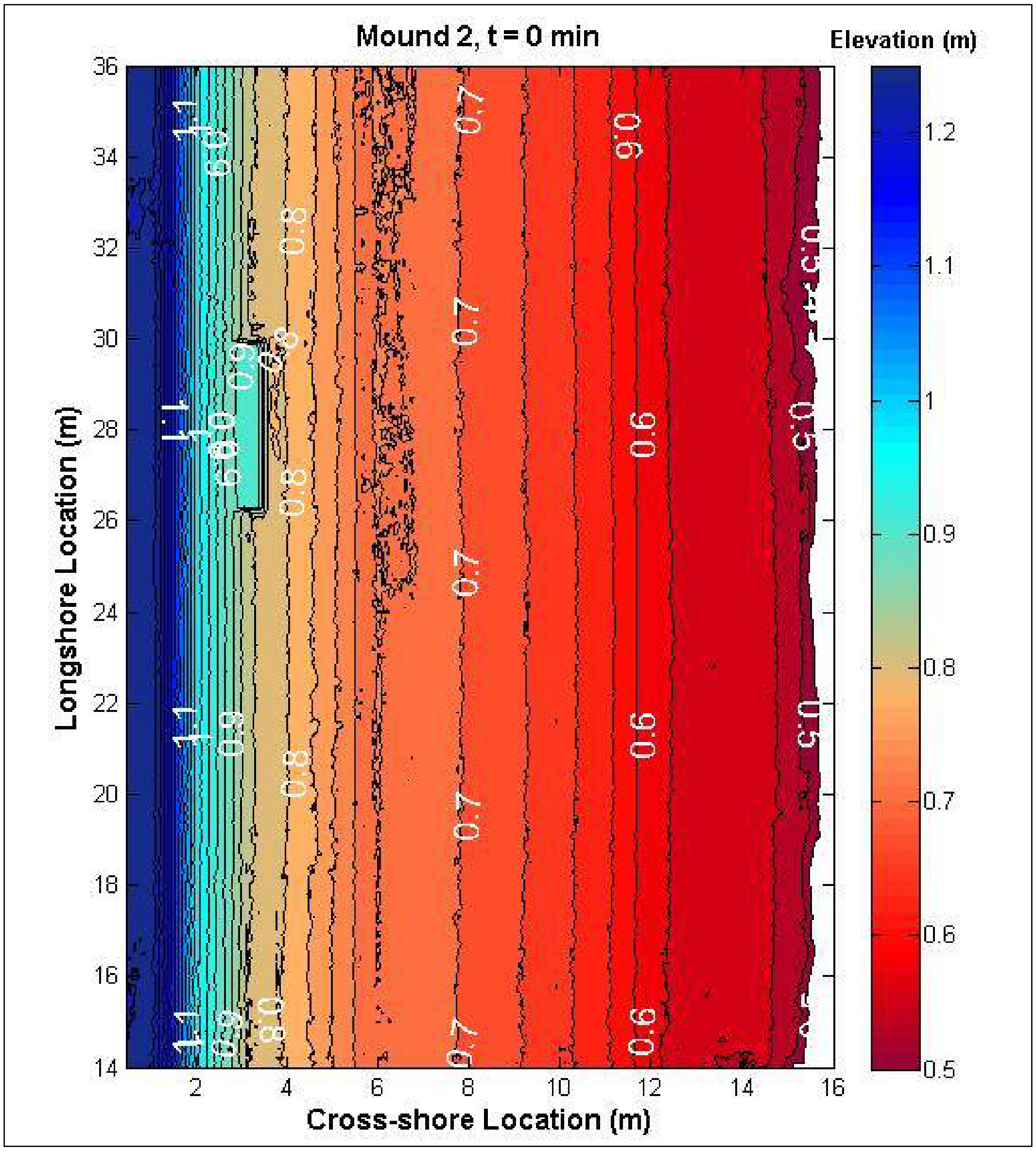


Figure 32. Panoramic view of the Mound 2 initial beach looking updrift.

Figure 33. Panoramic view of the Mound 2 initial beach.

Figure 34. Mound 2 initial beach looking offshore.

Figure 35. Mound 2 bathymetry after 120 min of waves.

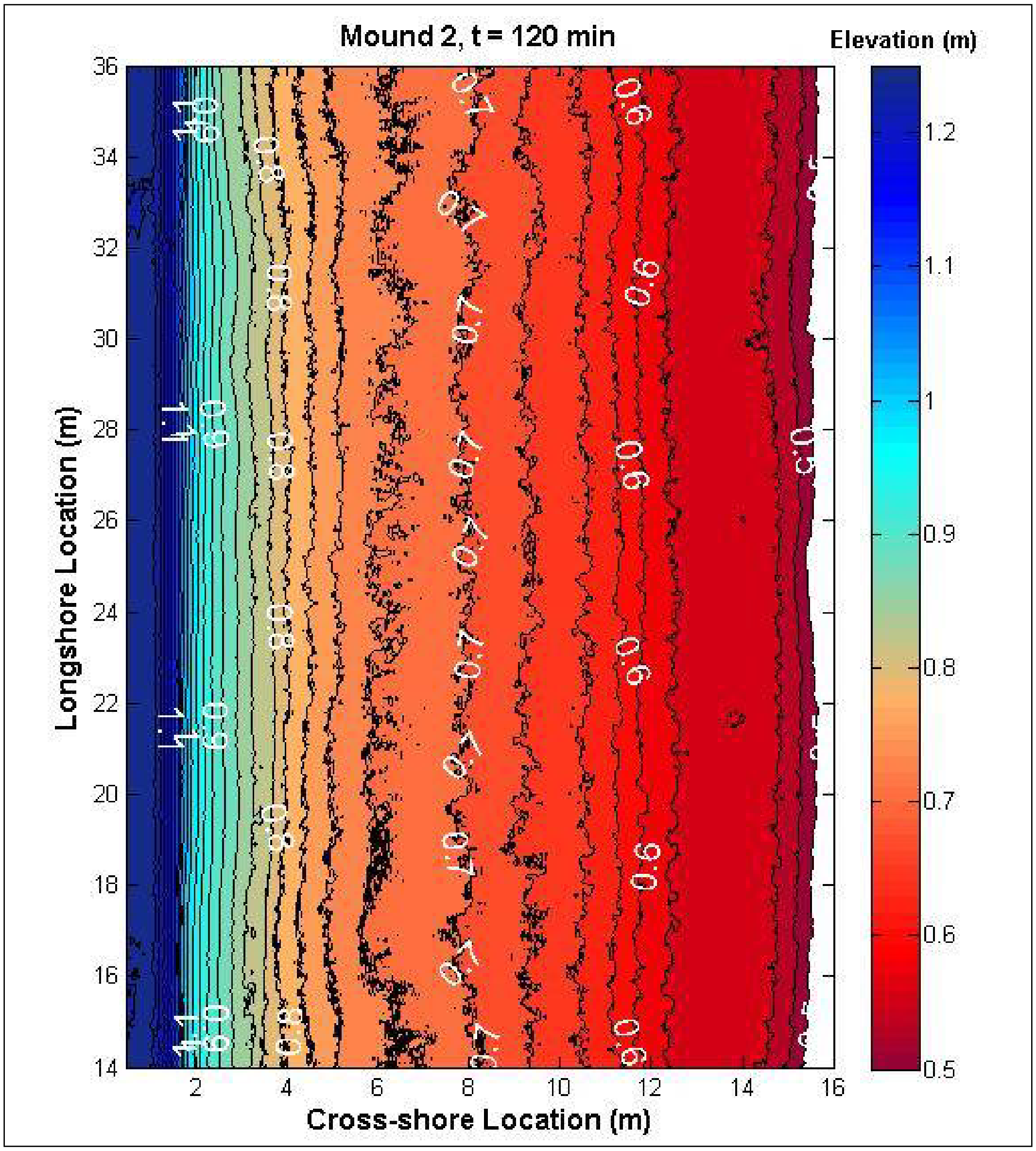


Figure 36. Panoramic view of the Mound 2 beach looking updrift after 120 min of waves.

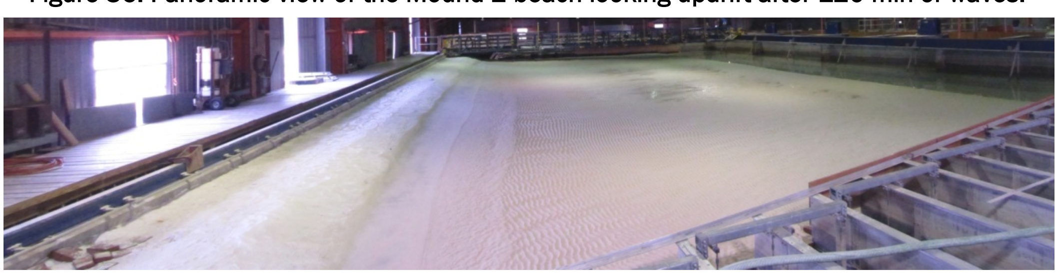
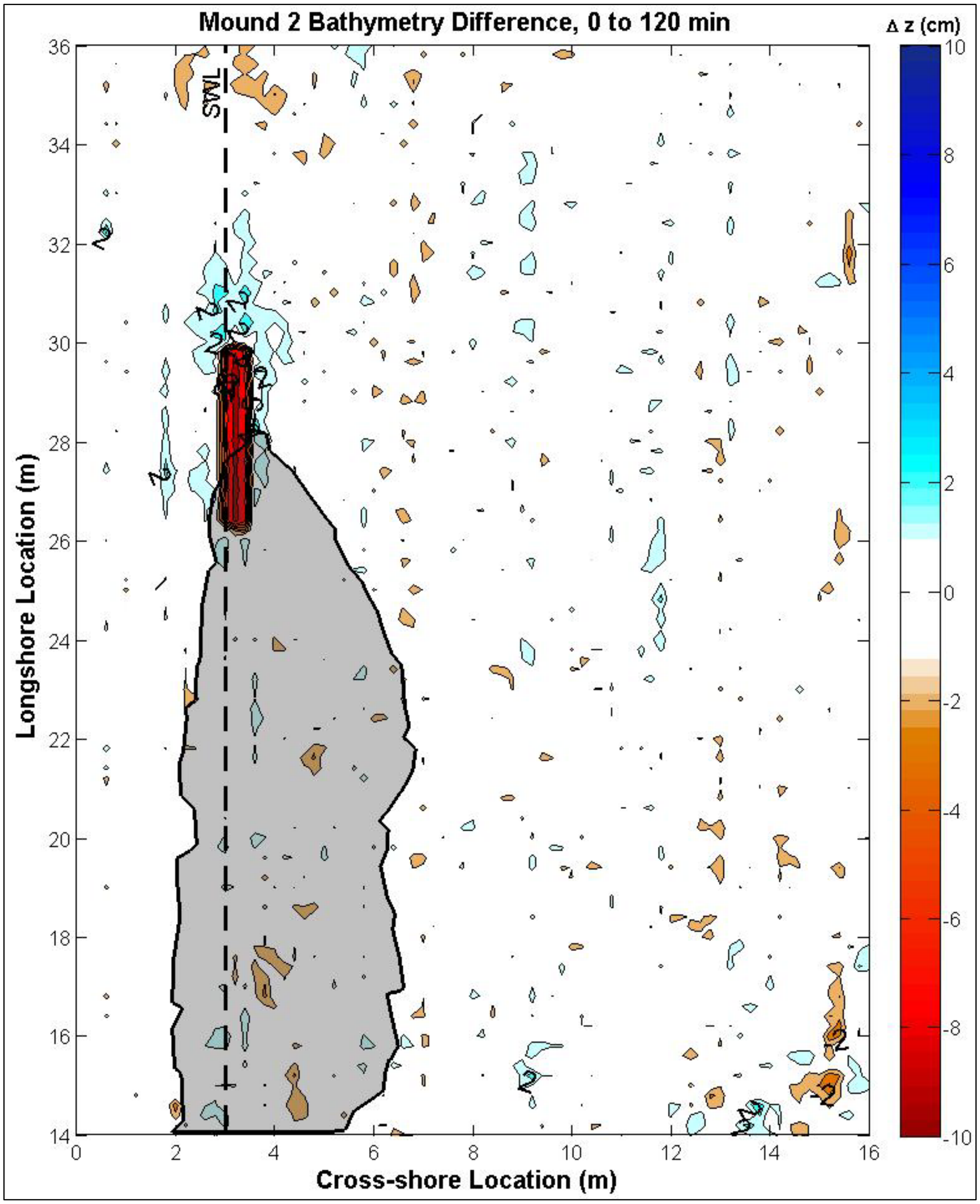


Figure 37. Panoramic view of the Mound 2 beach after 120 min of waves.

Figure 38. Mound 2 beach looking offshore after 120 min of waves.

Figure 39. Photograph of Mound 2 sand samples collected after 120 min of waves at alongshore locations (from left to right): Y34, Y30, Y28, Y26, Y22, and Y18.

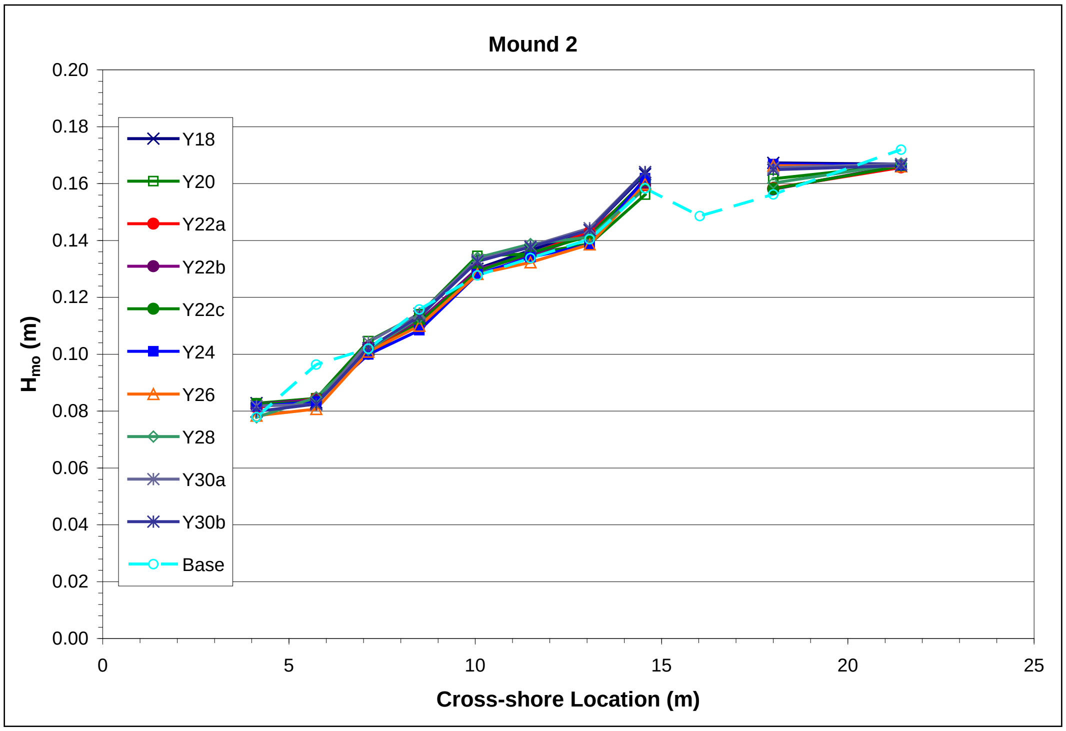
Figure 40. Mound 2 relative bathymetry difference after 120 min of waves.



No significant areas of erosion are present onshore and downdrift of the mound, which may be a result of mound sand feeding the longshore transport. Sand from Mound 2 was transported alongshore farther than sand from Mound 1, which is related to the shallower depth and higher longshore currents at the Mound 2 placement location. The beach behavior also is similar to a detached breakwater in that longshore transport is disrupted, accumulating sand updrift and in the vicinity of the mound placement site.

Figure 41 shows the cross-shore distribution of wave heights with Mound 2. Gauge 9 stopped operating during the test and is not included. Wave heights are similar to the Base Condition through the surf zone except at the Gauge 2 (X = 5.73 m), which measured lower heights over the length of the beach. The alongshore uniformity at the location indicates the lower wave heights were not influenced by the localized placement of sand.

Figure 41. Cross-shore distribution of wave height for Mound 2.



The majority of mound sand moved onshore or downdrift of the mound. The survey and photographs of the beach with dyed sand indicate the mound sand remained in the surf zone.

3.4 Mound 3

Mound 3 was constructed on the foreshore slope between Y = 26 m and Y = 30 m at a model scale elevation of 0.12 m above swl to represent an elevation of 2.4 m at a 1:20 scale. The mound was constructed with 0.21 m^3 (7.4 ft^3) of orange-dyed sand to represent 1,680 m^3 (59,300 ft^3). Figure 42 shows the cross-sectional profile of the Mound 3 beach at the mound centerline (Y = 28) and at Y = 22 m for Mound 3 and the Base Condition. The Mound 3 profile at Y = 22 m agrees with the Base Condition over most of the profile; however, the profile is lower than the Base Condition between X = 2 and 3 m. Bathymetry is given in Figure 43, which shows some

divergence of the contours downdrift of the mound between X = 7 and 8 m in which the profile elevation is high. Photographs of Mound 3 are shown in Figures 44 and 45 as the basin was being filled with water prior to the first test segment. The waterline is nonuniform in Figure 44, looking updrift, and illustrates the region where the profile is high downdrift of the mound.

Bathymetry after 120 min of waves on the Mound 3 beach is shown in Figure 46. The final profile shows only a small indication of the mound presence. The bathymetry shows an irregularity in the contours at Y = 17 m that is believed to be associated with boundary effects. This anomaly is present in the other mound tests but is much more apparent for Mound 3. Photographs of the Mound 3 beach after 120 min are shown in Figure 47 through 49. Mound sand was transported from its original location to the downdrift boundary (Figure 47), and little of the material is visible on the surface near the original alongshore placement (Figure 49). Sand samples taken at the cross-shore centerline of the mound are shown in Figure 50 for alongshore locations of (left to right) Y = 30, 28, 26, 22, 20, and 18 m. Figure 50 shows much of the orange (mound) sand remained at the original placement location (Y = 28 m) but mixed with the native sand. Orange sand is present and mixed with the native sand in all of the samples to depths ranging from 1.4 cm to 2.5 cm.

Figure 42. Mound 3 initial beach profile compared to the Base Condition profile.

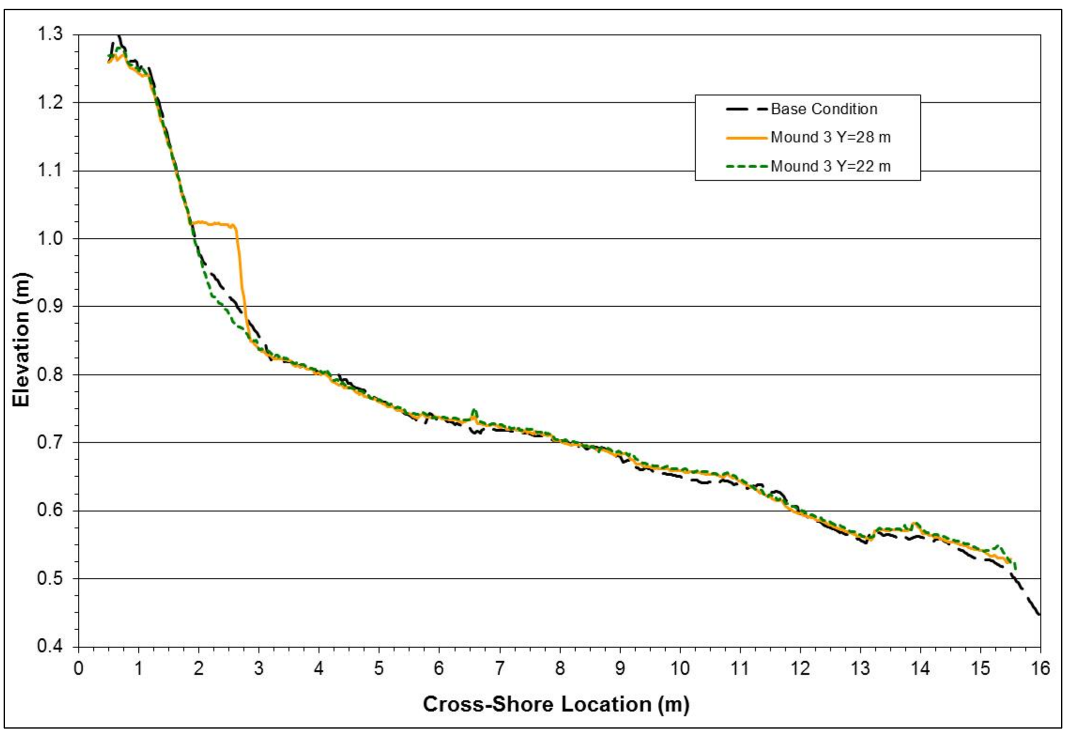


Figure 43. Mound 3 initial bathymetry.

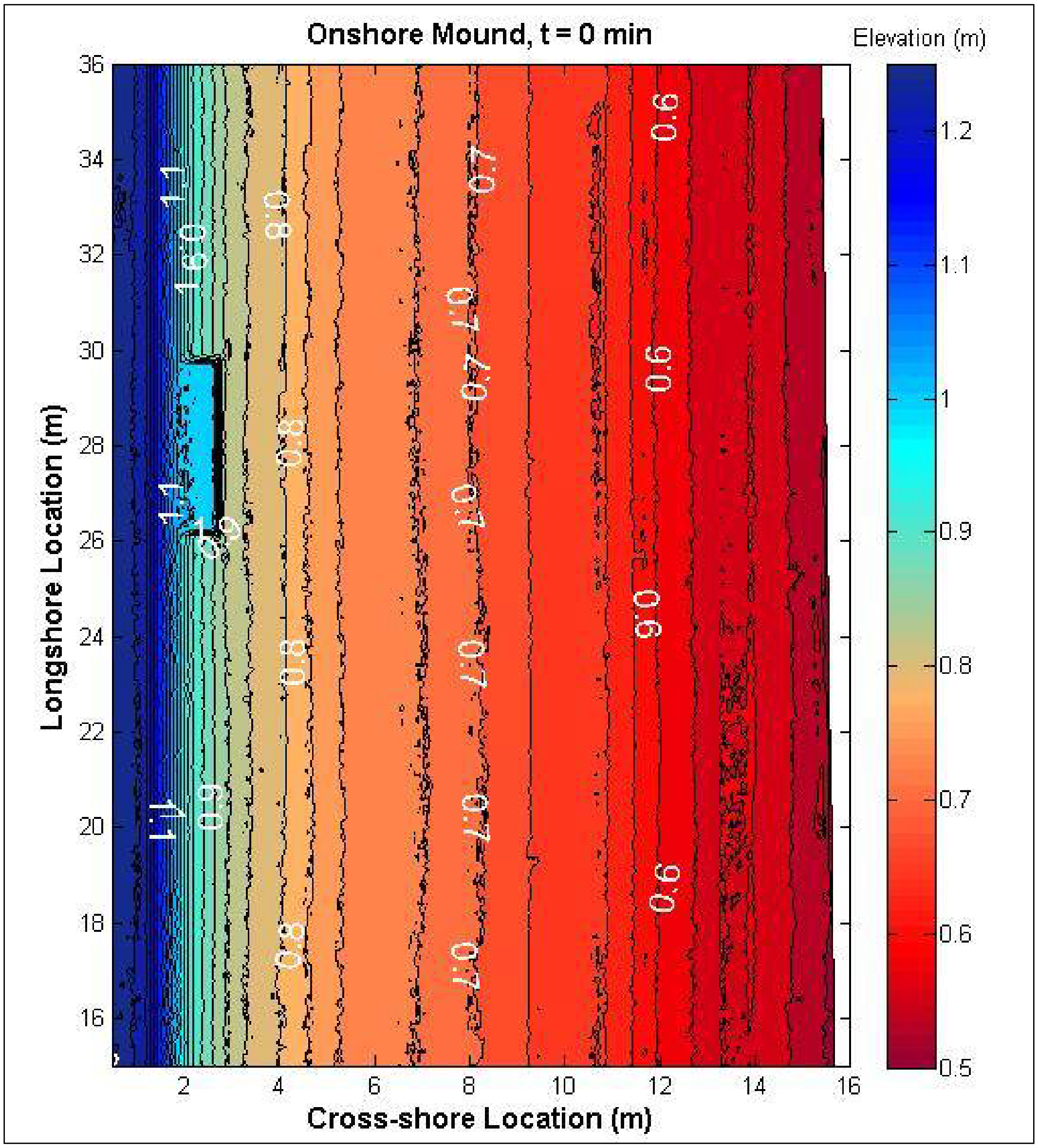


Figure 44. Panoramic view of the Mound 3 initial beach looking updrift.

Figure 45. Mound 3 initial beach looking offshore.

Figure 46. Mound 3 bathymetry after 120 min of waves.

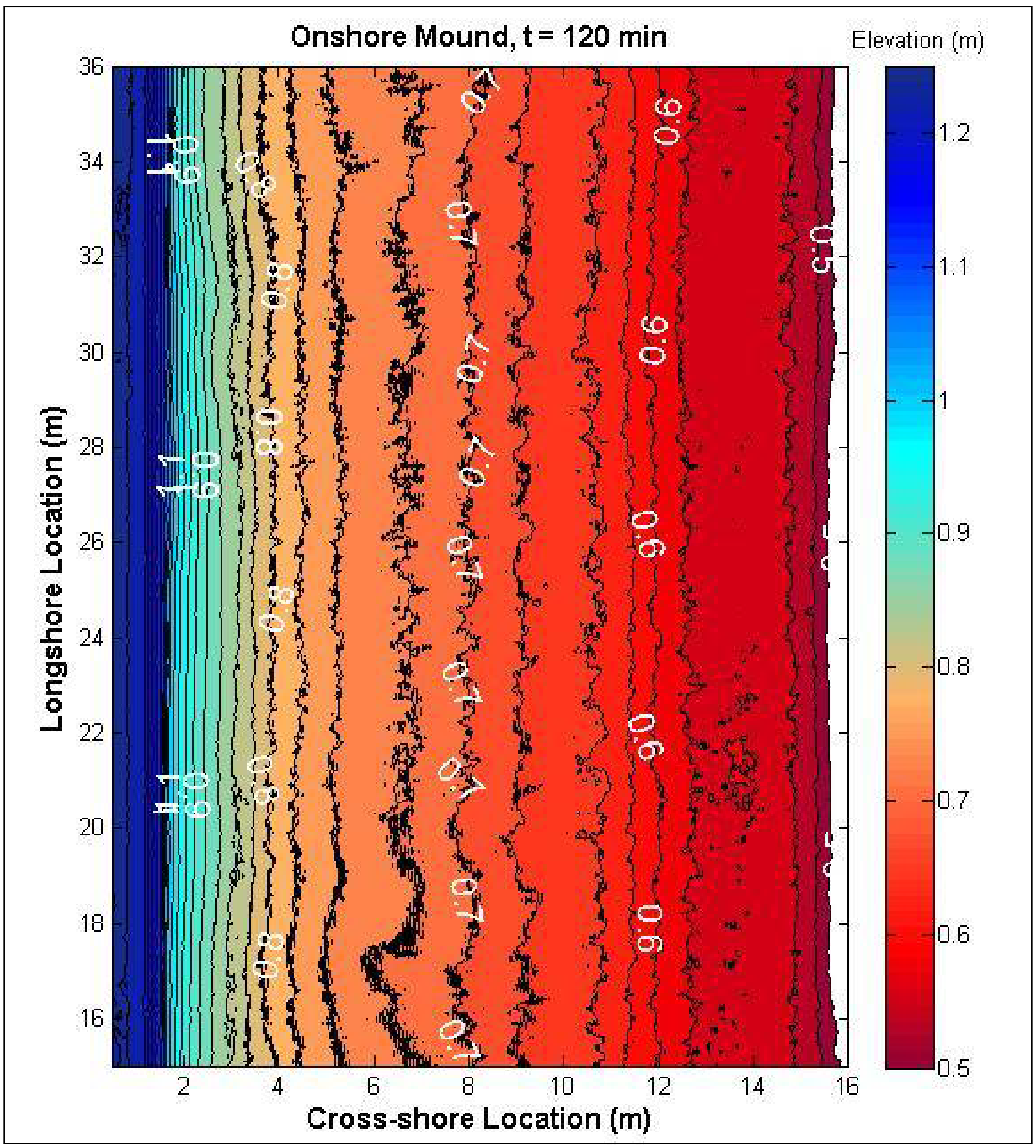


Figure 47. Panoramic view of the Mound 3 beach looking updrift after 120 min of waves.

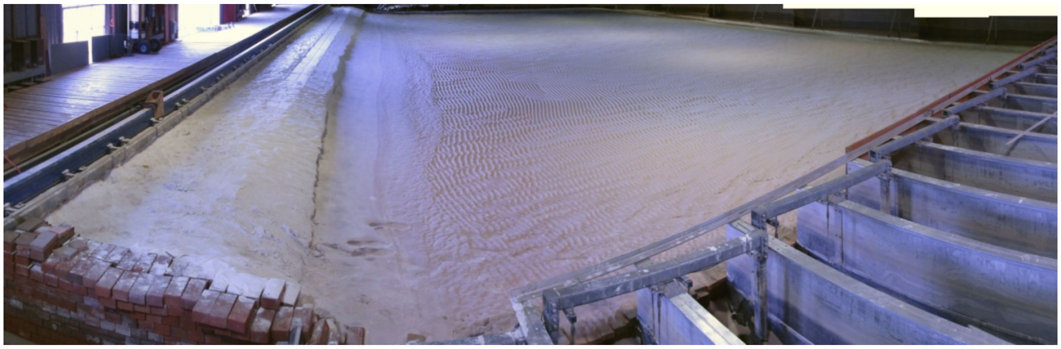


Figure 48. Panoramic view of the Mound 3 beach after 120 min of waves.

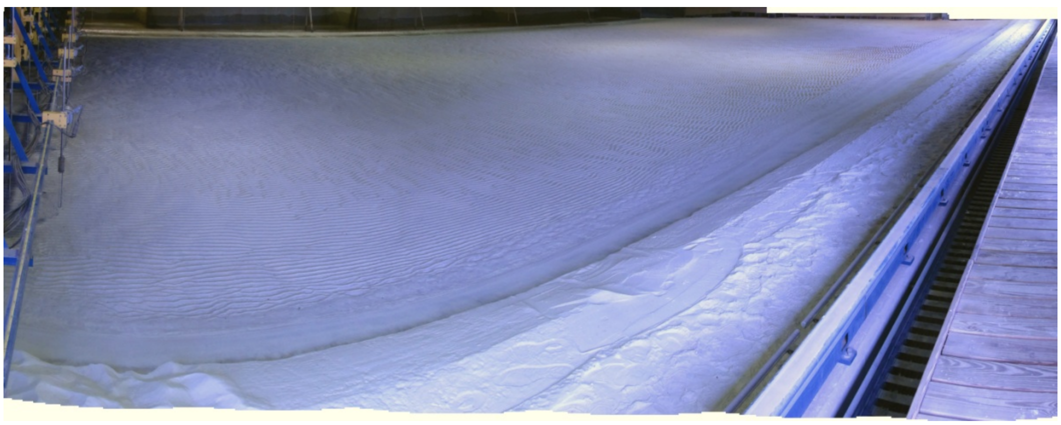


Figure 49. Mound 3 beach looking offshore after 120 min of waves.

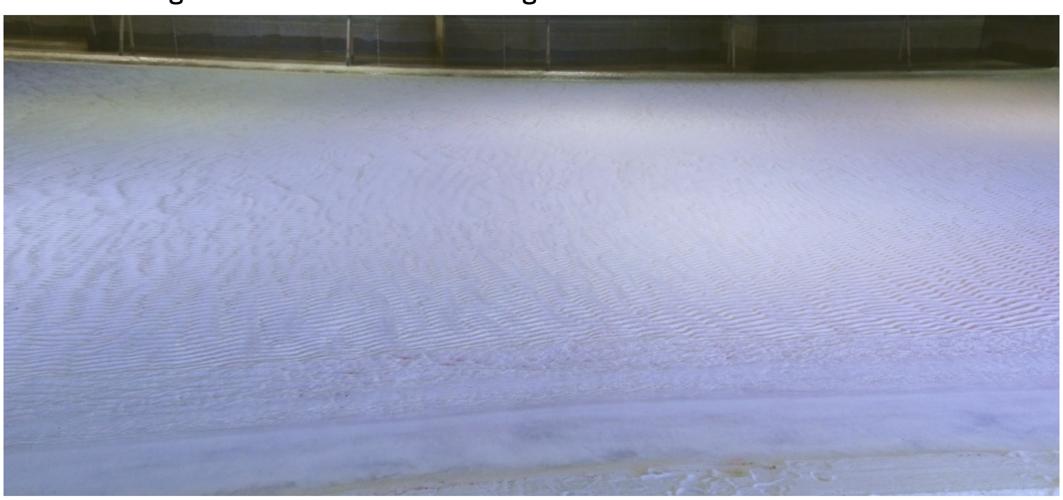


Figure 50. Photograph of Mound 3 sand samples collected after 120 min of waves at alongshore locations (from left to right): Y30, Y28 Y26, Y24, Y20, and Y18.

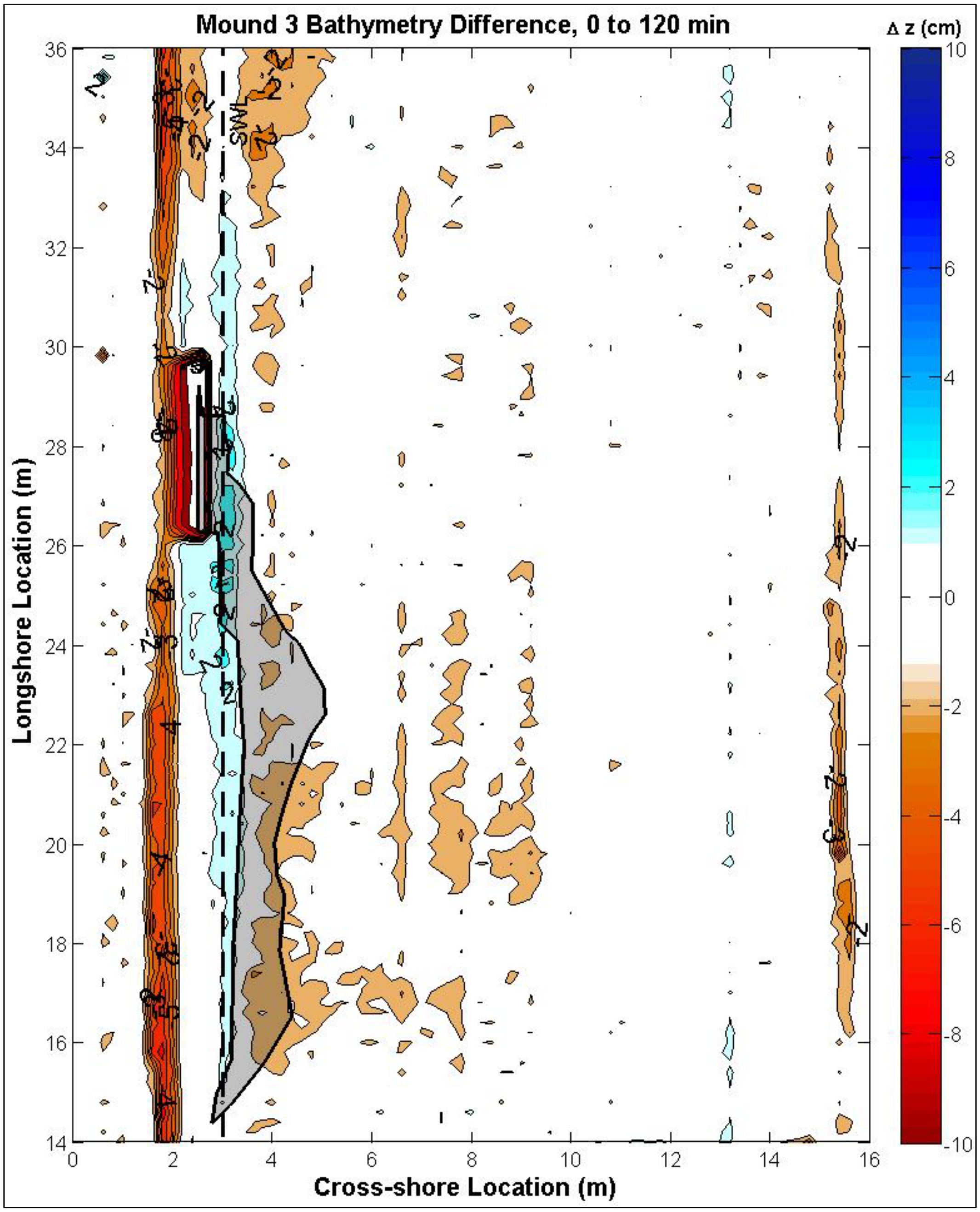
Elevation differences over the duration of the Mound 3 test are given in Figure 51. Accretion is observed mainly downdrift and directly offshore of the mound but also updrift of the original mound location. Accumulation due to the mound was restricted to the swash zone and particularly at the shoreline.

Erosion is evident over much of the beach. The erosion onshore in the vicinity of X ≈ 2 m is a result of the larger scarp formation formed during Mound 3 tests (Figure 47). Scarp formation in the vicinity of the mound was much less than the areas updrift and downdrift of the location. Erosion also occurred downdrift of the mound in many areas between X=3.5 and 10 m. Additionally, a line of erosion is evident near the offshore boundary. Differences between the Mound 3 and Base Condition beaches near the shoreline are the likely reasons for the more pronounced scarp and additional erosion areas offshore of the mound. Figure 42 shows that the Mound 3 profile is lower than the Base Condition profile between X=2 and 3 m at Y=22 m. Differences also were present between the Base Condition and Mound 1 and Mound 2 beaches (Figures 15 and 30, respectively); however, the differences with Mound 3 occurred near the shoreline. The lower elevation near the shoreline potentially could have promoted erosion of the foreshore slope, leading to the scarp.

The Mound 3 dyed sand was observed to be very faint after 120 minutes (Figures 47 to 49). The area of surface mound sand is shown by the shaded area in Figure 51, which shows that the mound sand was transported downdrift slightly offshore of the shoreline and covers portions of eroded

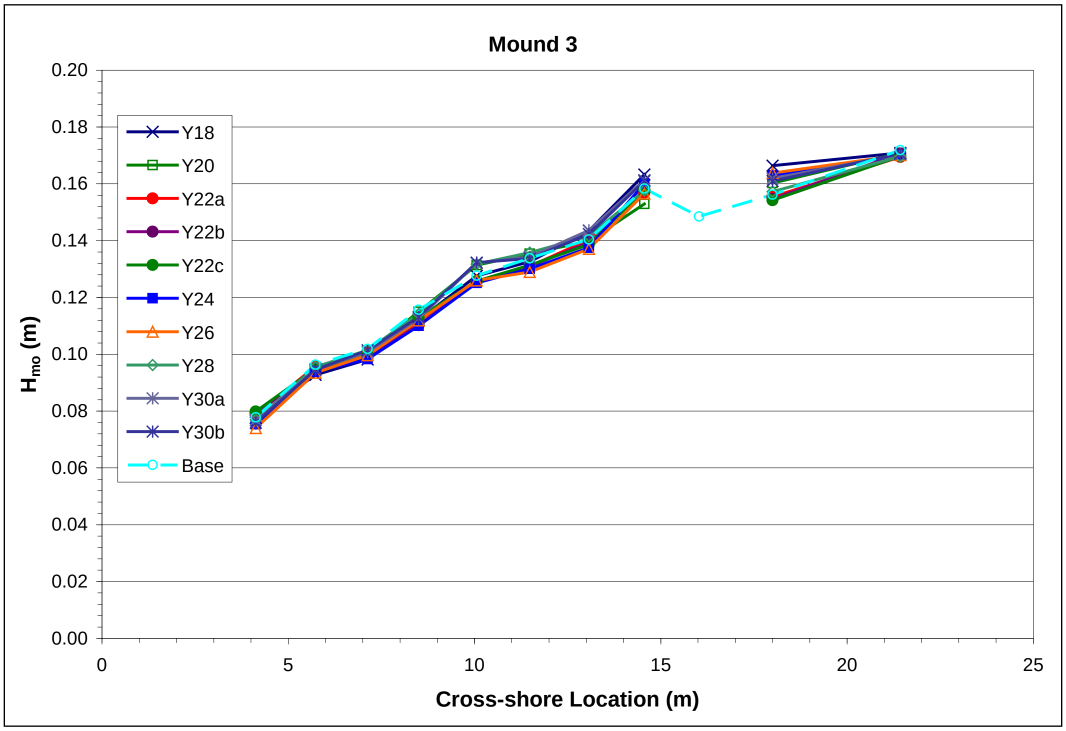
beach. Although the shaded area indicates the mound sand didn't cause accretion, Figure 50 indicates mound sand mixed with the native sand and contributed to the accretion observed directly downdrift of the initial mound location.

Figure 51. Mound 3 relative bathymetry difference after 120 min of waves.



The cross-shore distribution of wave heights with Mound 3 is shown in Figure 52. Gauge 9 (not operating) measurements were not included. Wave heights are generally uniform but show more longshore variability than the other mound tests. Heights are slightly lower than the Base Condition onshore of X = 10 m.

Figure 52. Cross-shore distribution of wave height for Mound 3.



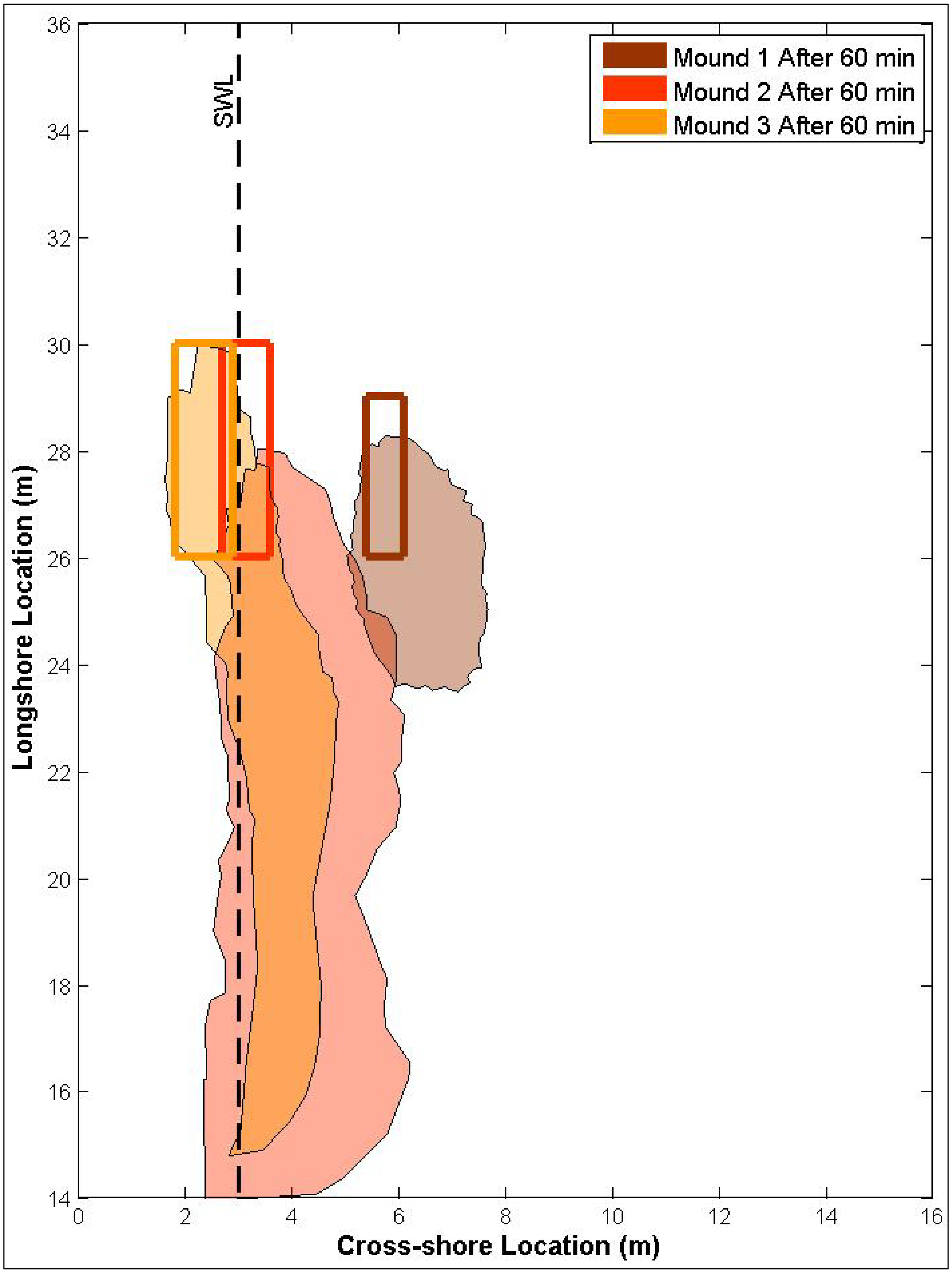
The Mound 3 figures indicate mound sand remained near the shoreline but was transported both updrift and downdrift of the mound. Bathymetry differences in the Mound 1 and Mound 2 tests showed isolated areas of accretion and erosion offshore of the mounds, and this result was expected in the Mound 3 tests. However, the Mound 3 beach morphology shows greater erosion in the offshore beach downdrift of the mound location, due to the excess sand in the constructed profile in this region. Regardless, the data and photographs indicate that sand placed in the mound remained in the surf zone.

3.5 Mound fate

Sand placed in mounds was dyed to visually determine the fate of the placed sand. The location of the sand following a test segment was determined through image processing. Figures 28, 40, and 51 show the bathymetry change and location of the dyed mound sand after 60 min with

Mound 1 tests and 120 min of wave action for Mounds 2 and 3. To directly compare transport of the placed sand, the area covered by mound sand for each test is shown in Figure 53 after 60 min of waves. Sand from Mound 1 was transported downdrift 2.5 m from its placement location, whereas Mound 2 sand was transported more than 12 m, past the downdrift boundary, and Mound 3 sand was transported 11.2 m downdrift. The longshore current velocity is greater at the cross-shore locations for Mounds 2 and 3 than at Mound 1 (Figure 4), and Figure 53 illustrates the influence of local longshore current on the transported mound sand. Additionally, all three mounds show transport slightly offshore, which is a result of the erosive wave condition generated for the experiments.

Figure 53. Mound sand fate after 60 min of waves.



4 Summary and Conclusions

4.1 Summary

Experiments were performed at a 1:20 undistorted scale in the LSTF to examine the design, evaluate the fate, and help quantify the benefits of nearshore-placed dredged material. Tests were conducted with waves that simulated a 6.7 s peak period and a 3.6 m wave height, H_{mo}, and included three nearshore mound locations at 3.4 m and 1.2 m depths, and onshore placement at an elevation of 2.4 m. A base condition also was performed with no mound to compare with the mound beach bathymetry and minimize the effects of beach profile evolution.

All of the mounds were dyed to enhance contrast of the mound sand with the beach sand, which allowed tracking of the mound sand through digital image processing. The mounds dispersed rapidly, and beach surveys were made every 10 min (44.7 min prototype) in the first 30 min (134.2 min prototype), by which time most of the mound had dispersed. Additional surveys were taken after 60 (268.3 min prototype) and 120 min (536.7 min prototype) of waves. Negligible beach change was observed after 120 min. The following paragraphs summarize the results from each of the mound tests

4.1.1 Mound 1

Mound 1 was placed at a model depth of 0.17 m (3.35 m prototype depth). The survey after 120 min of waves was not available; however, beach changes after 60 min indicated that accretion occurred onshore of the mound. In particular, sand accreted on the foreshore slope directly onshore of the mound. Some sand accumulated offshore of the mound but remained in the surf zone. The dyed mound sand was transported downdrift and slightly offshore, indicating that accretion onshore of the mound may have been a result of wave sheltering effects of the initial mound. Sand samples taken at alongshore locations along the cross-shore centerline of the mound showed that mound sand mixed with native sand as it was transported downdrift.

4.1.2 Mound 2

Mound 2 was constructed at a model depth of 0.06 m (1.2 m prototype depth). Longshore currents were higher at the Mound 2 cross-location than the Mound 1 location, and the mound sand was distributed alongshore from the original placement location to the downdrift boundary. Samples taken at alongshore locations along the cross-shore centerline of the mound indicated mixing of the mound sand with native sand at all downdrift sample locations. Beach changes after 120 min showed accumulation onshore and both downdrift and updrift of the mound location. It is believed that the updrift accumulation was due in part to sand transported from updrift depositing when encountering the shallower water near the mound.

4.1.3 Mound 3

Mound 3 was placed on the foreshore slope at a model elevation of 0.12 m (2.4 m prototype). Sand from the mound was transported alongshore to the downdrift boundary. Little of the dyed sand was visible on the bed surface; however, sand samples taken alongshore of the placement location showed mound sand mixed with native sand in the bed for all samples, including updrift of the mound. Accretion was observed in the swash zone immediately downdrift of the mound placement and along the shoreline updrift and downdrift of the mound. The results are similar to those of a field monitoring study at Perdido Key, FL (Wang et al. 2013), in which much of the material placed in the nearshore and swash zone was transported rapidly to the adjacent beach and into the shallow portion of the beach profile.

More erosion was observed with this test than with the two submerged mounds. A scarp formed that extended the entire length of the beach. Figure B10 in Appendix B shows that the scarp began forming within the first 10 min of waves and extends the entire beach length, implying that the beach was constructed out of equilibrium. The Mound 3 beach was constructed lower than the Base Condition beach near the shoreline, and the increased erosion may be due to this difference. Also, poor compaction of the constructed profile at the shoreline and foreshore slope could cause excessive erosion and lead to the scarp formation. Areas of erosion occurred downdrift and offshore of the mound, an artifact of the excess sand in constructed profile at this location.

4.2 Conclusions

The results for the particular wave forcing condition in this study indicated that sand placed in the nearshore remained within the littoral system. This determination was one of the goals of the experiment. The additional sand in the system provides additional volume to the active beach. Sand from each of the mounds dispersed quickly alongshore, mixed with the native sand, and was transported predominately downdrift in the active surf zone.

No onshore accretion was apparent as a direct result of the cross-shore transported mound sand for the two submerged mounds, Mounds 1 and 2, placed offshore of the shoreline. However, the beaches did accrete onshore of the mound position and in the vicinity of the mound placement, indicating the perturbation of the mound altered wave and current conditions such that sand was deposited in the lee of the mounds. Mound 1, placed farthest offshore, also showed a disruption in longshore transport, which resulted in erosion downdrift of the mound. The potential impacts to downdrift beaches need to be examined prior to placement of material in the nearshore.

Different results were observed for Mound 3, placed on the foreshore, than with the two submerged mounds. Erosion was observed on the beach, which was caused by a discrepancy between the constructed and target beach templates near the shoreline. Therefore, it was not possible to assess bathymetric changes on the target beach due to the foreshore placed mound. Despite the additional erosion caused by construction inaccuracy, mound sand remained in the littoral system. Additionally, accretion was observed throughout the swash zone, particularly directly downdrift of the mound location and near the shoreline. Dyed mound sand was present in sand samples taken both updrift and downdrift of the placement location, indicating mound sand directly contributed to the accretion.

The study demonstrated that nearshore mound placements can provide an immediate benefit to beaches with respect to increased profile volume or accretion to the subaerial shoreface. Beach change from the two submerged mounds, Mound 1 and 2, were slight and provided qualitative information; however, little quantitative guidance was obtained on the effects of placement depth. Both Mound 1 and 2 performed similarly to that of a detached breakwater in that most shoreward morphologic changes likely resulted from differences in wave energy leeward of the

mound. These results contrasted with the results of the subaerial placement of Mound 3, placed on the foreshore slope. The Mound 3 placement resulted in substantial changes at the shoreline due to the mound presence and subsequent alongshore transport of the sand in the active swash-zone of the downdrift cross-shore profile.

4.3 Discussion and recommendations for future tests

The laboratory experiments were limited in their capacity to model a variety of natural wave and current conditions experienced in the field. The wave conditions were selected based on previously modeled wave, bathymetry, and longshore current conditions. The wave condition, a 6.7 s, 3.6 m wave at a 1:20 scale, corresponds to roughly a 2 yr wave event, which is much more energetic and erosive than typical conditions. It is unlikely material would be placed under these conditions in nature; waves and the resulting longshore currents would be much milder. Future experiments should include an accretionary wave condition that is representative of a daily environment to better quantify nearshore placed material benefits. However, experiments in the LSTF require an equilibrium profile and proper boundary forcing of the wave-driven longshore currents for a given wave condition. Presently there are four LSTF wave conditions with known currents and bathymetry. Future experiments may require preliminary tests to determine the wave-driven longshore currents and associated equilibrium profile for the wave condition.

The laboratory tests were accomplished over a relatively short duration; the 120 min of model time represent approximately 9 hr in the prototype at a 1:20 scale. Although nearly all of the sand in the mounds was dispersed during each mound test, longer experiments are required to observe beach response of the sand accreted due to the wave sheltering of the mound. In the LSTF, this may require emptying the traps and manually feeding or reconstructing the beach at the updrift boundary, especially if a milder wave condition is generated.

Samples were taken at alongshore locations at the cross-shore location of the mound. Although, no dyed sand was visible in accreted areas for Mounds 1 and 2, mixing of the mound sand with the native sand was evident in the samples taken at alongshore locations. No samples were taken in the cross-shore, but future experiments should include cross-shore samples to determine if mixing of the mound sand with native sand occurs.

One of the difficulties of constructing the beach is replicating the profile between the 1 m spaced control points, particularly in areas of curvature or slope change. The initial Mound 3 and Base Condition beaches deviated near the shoreline and in the offshore area where erosion was observed, which may have led to the scarp formation and erosion observed for that experiment. The reason for the deviation is unclear (e.g., human error, slippage of the grading boards). Regardless, an efficient method should be employed in future experiments to verify that the beach is built to the desired bathymetry as it is being constructed.

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Appendix A: Beach Contour Plots

The figures presented in this appendix include contour plots taken from beach surveys following each test segment for the Base Condition and three mound tests. In the figures, the offshore direction increases with cross-shore location; waves approach from the right. Longshore transport is directed from higher to lower longshore locations (i.e., from the top to the bottom of the figure). The contours represent elevations from the LSTF floor. The water level for all tests was 0.9 m; therefore, the shoreline is the 0.9 m contour.

Figure A1. Base Condition initial beach bathymetry.

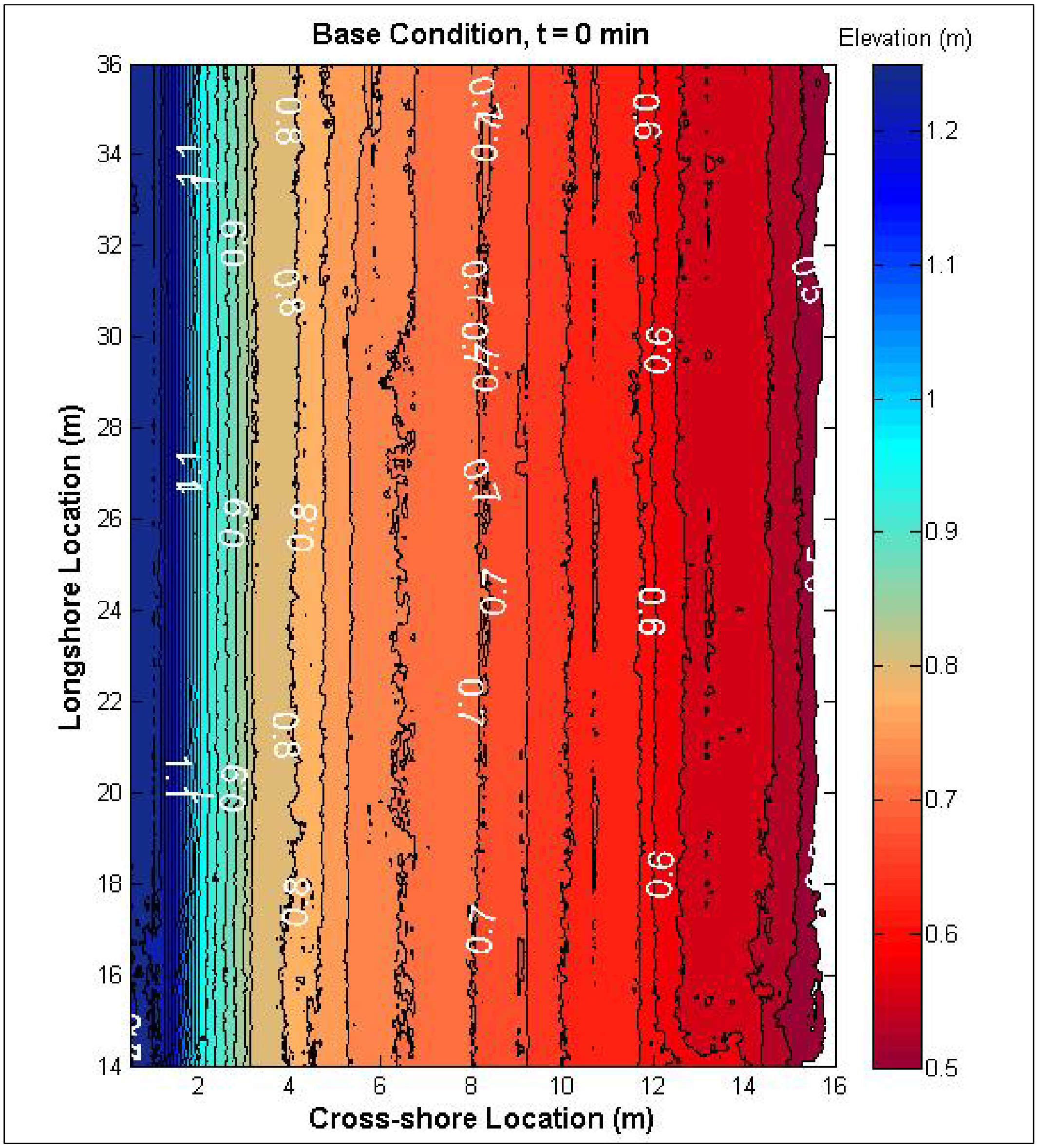


Figure A2. Base Condition bathymetry after 10 min of waves.

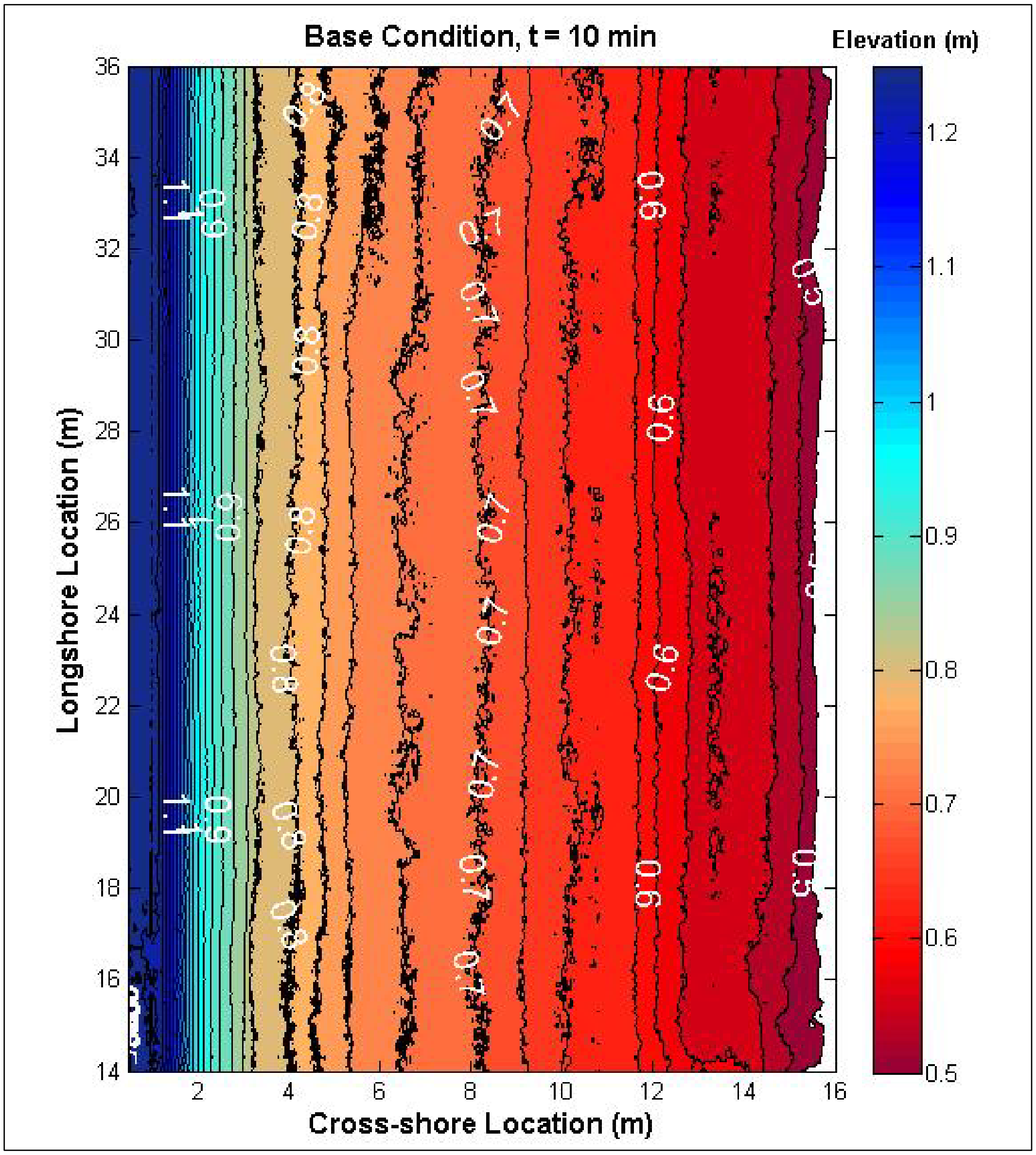


Figure A3. Base Condition bathymetry after 20 min of waves.

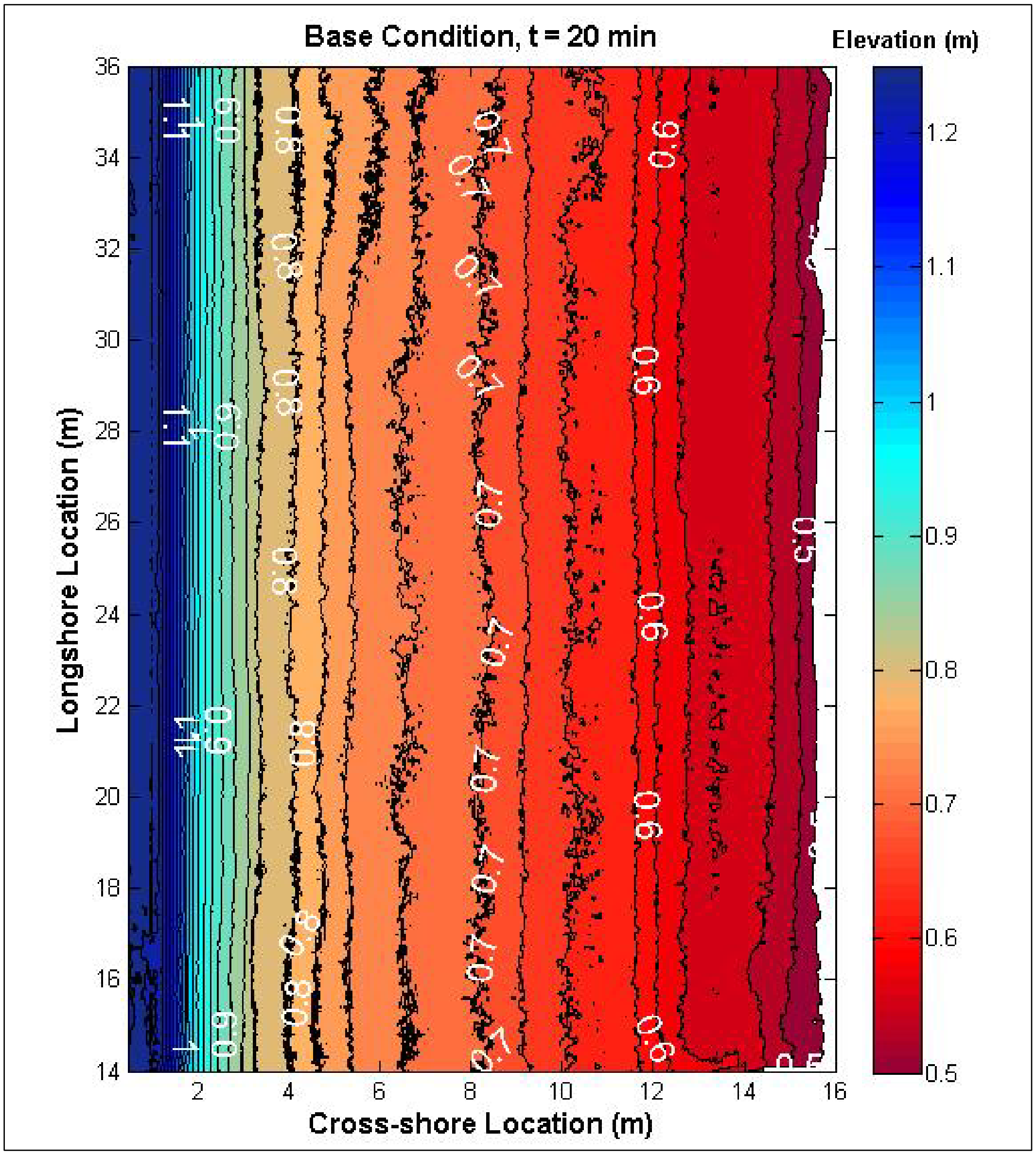


Figure A4. Base Condition bathymetry after 30 min of waves.

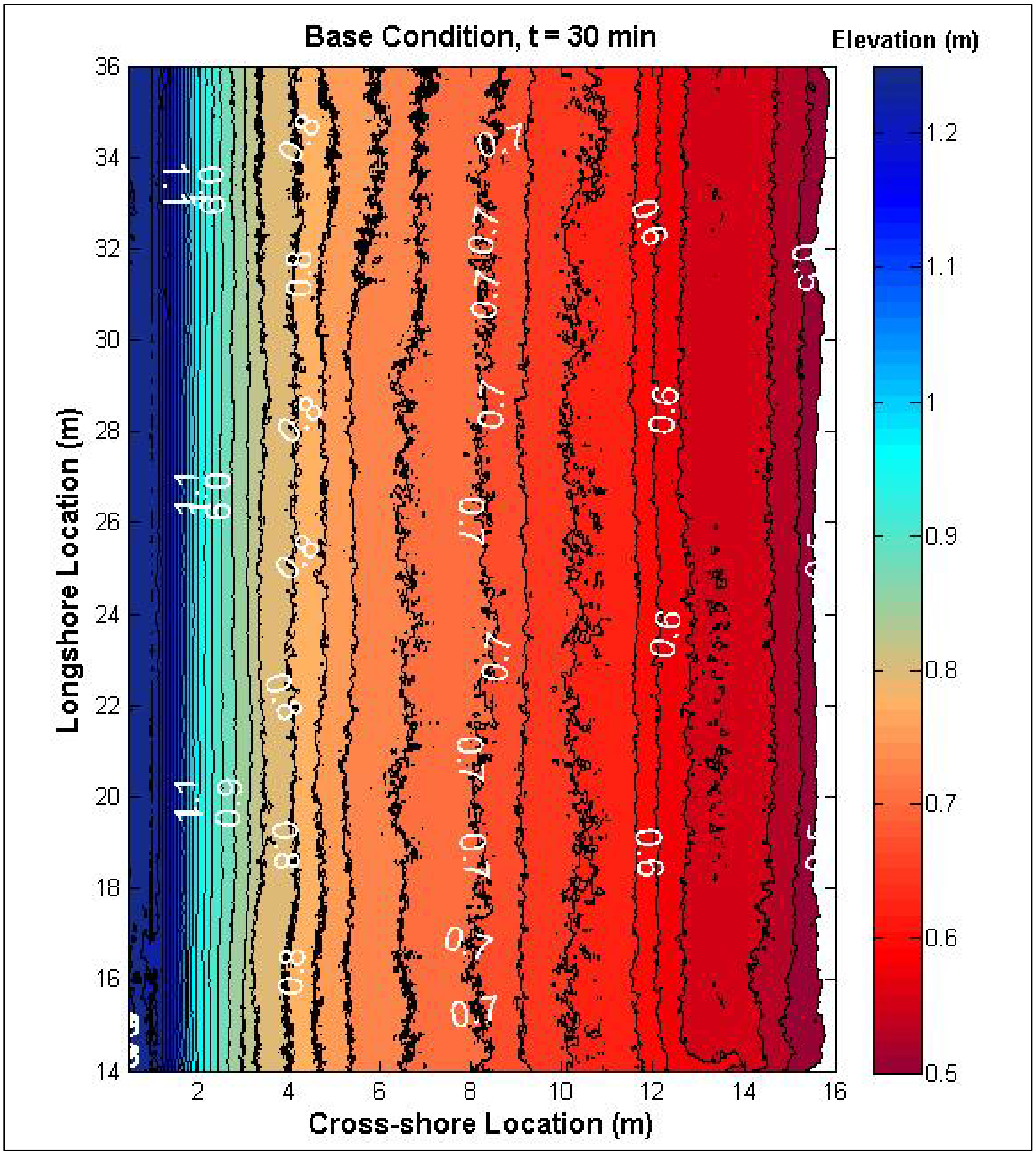


Figure A5. Base Condition bathymetry after 60 min of waves.

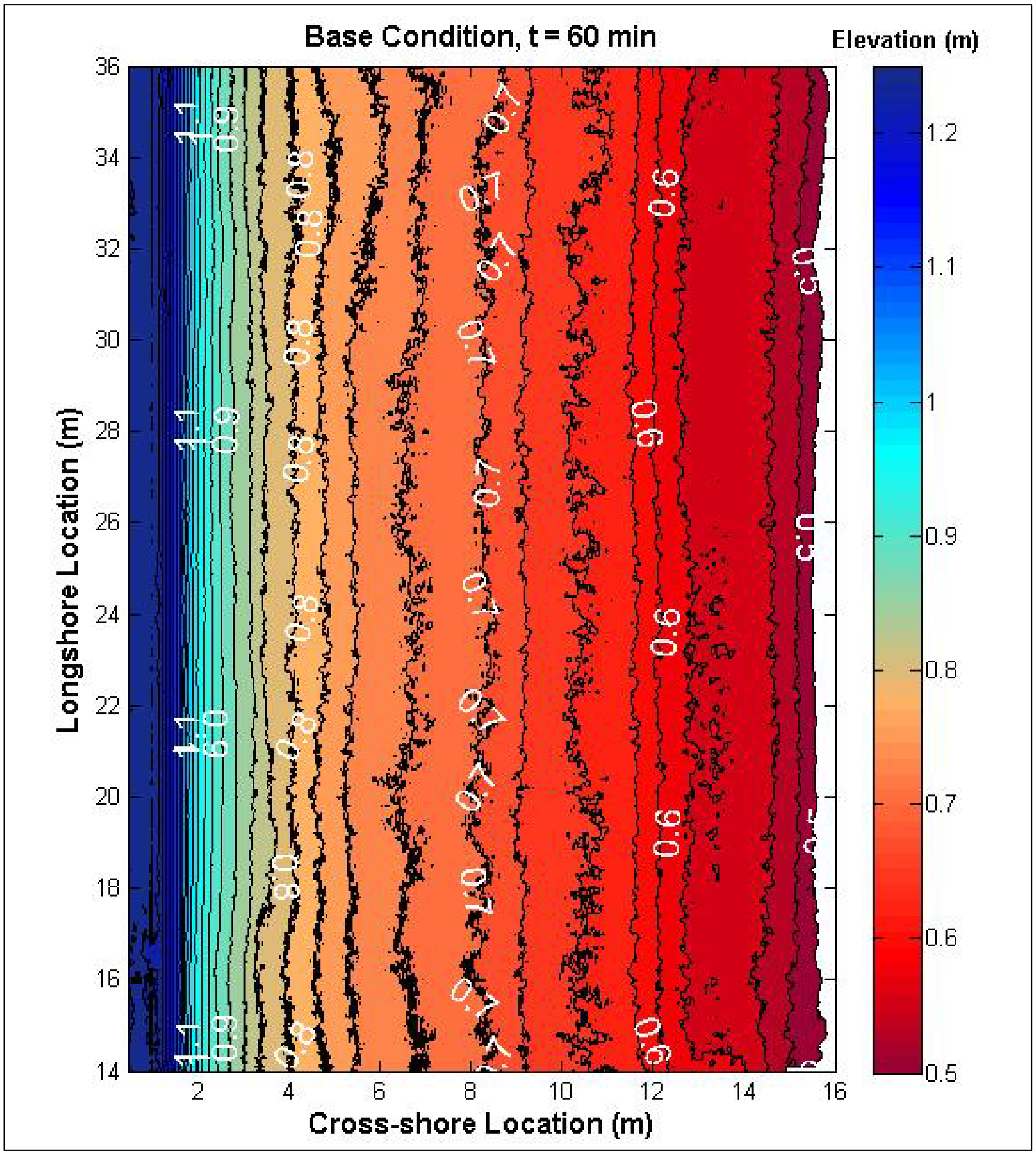


Figure A6. Base Condition bathymetry after 120 min of waves.

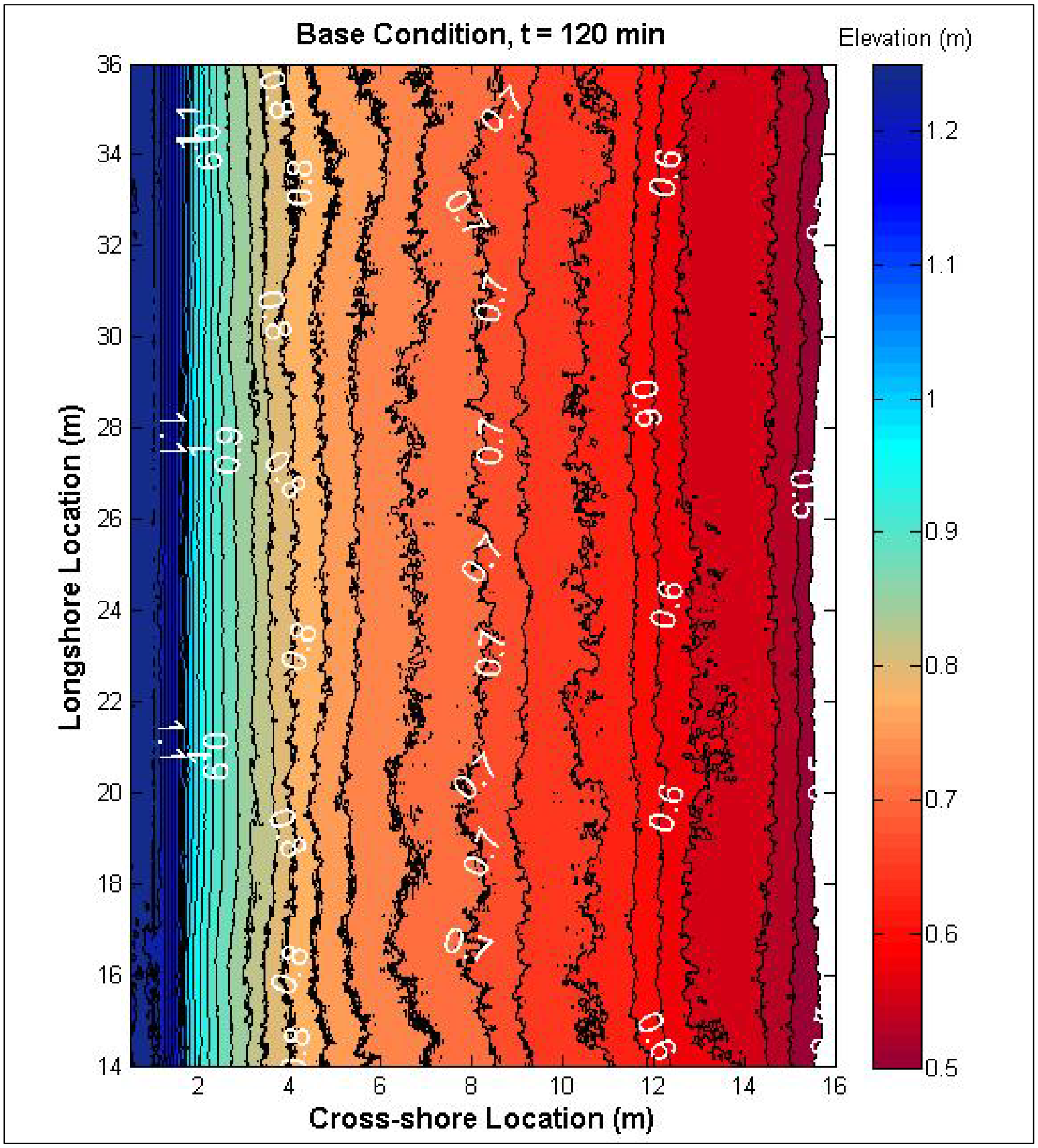


Figure A7. Mound 1 initial beach bathymetry.

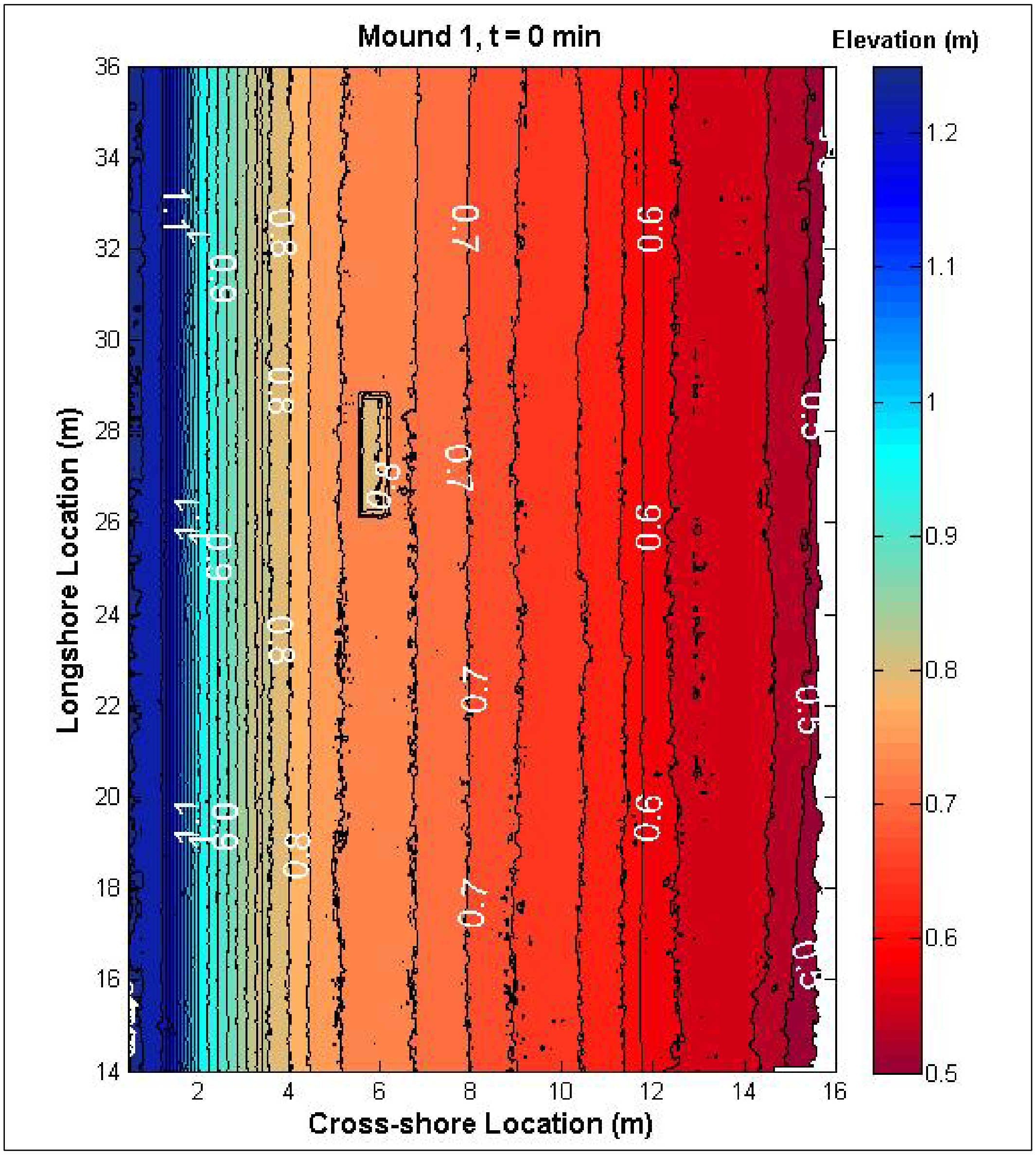


Figure A8. Mound 1 bathymetry after 10 min of waves.

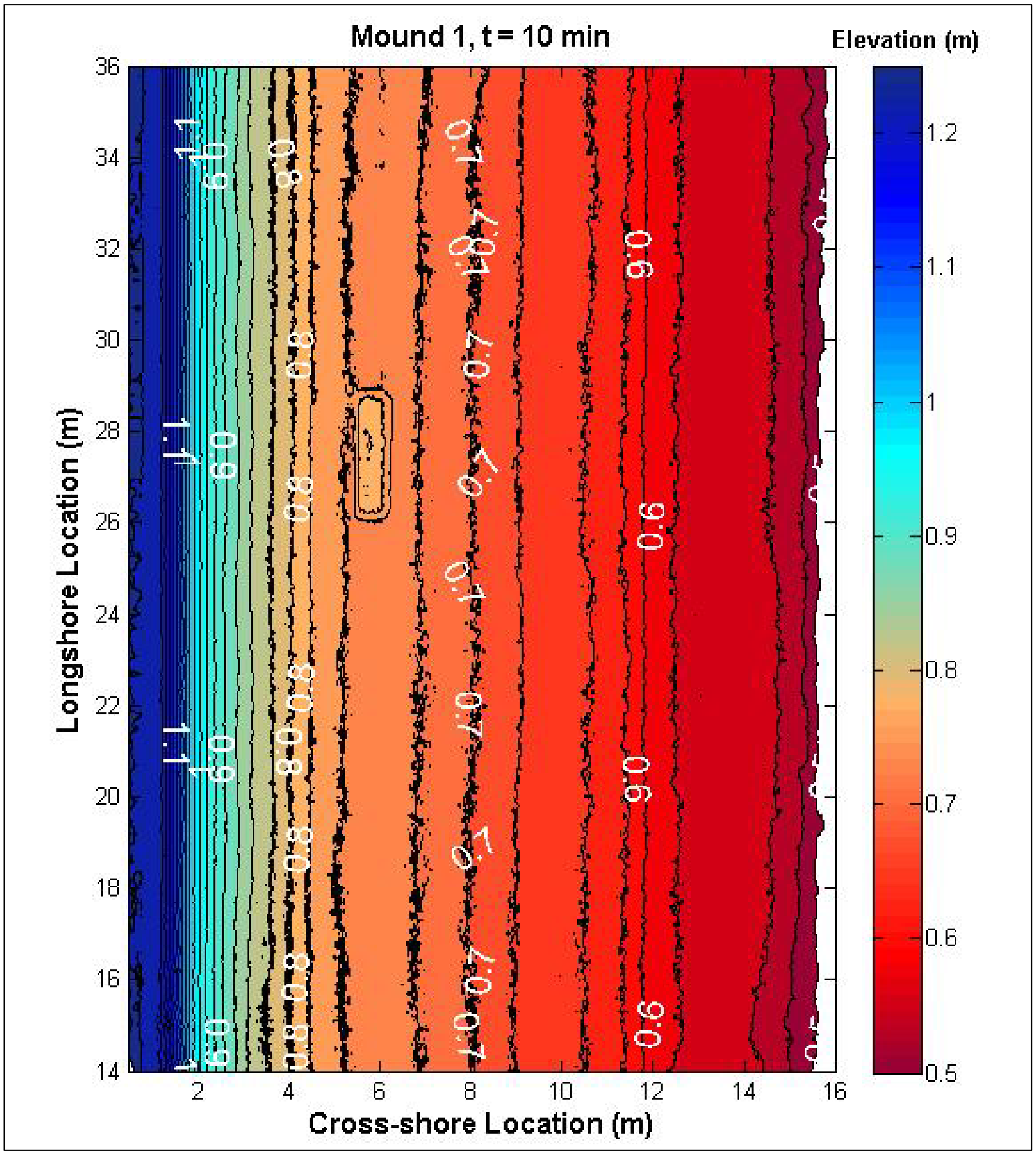


Figure A9. Mound 1 bathymetry after 20 min of waves.

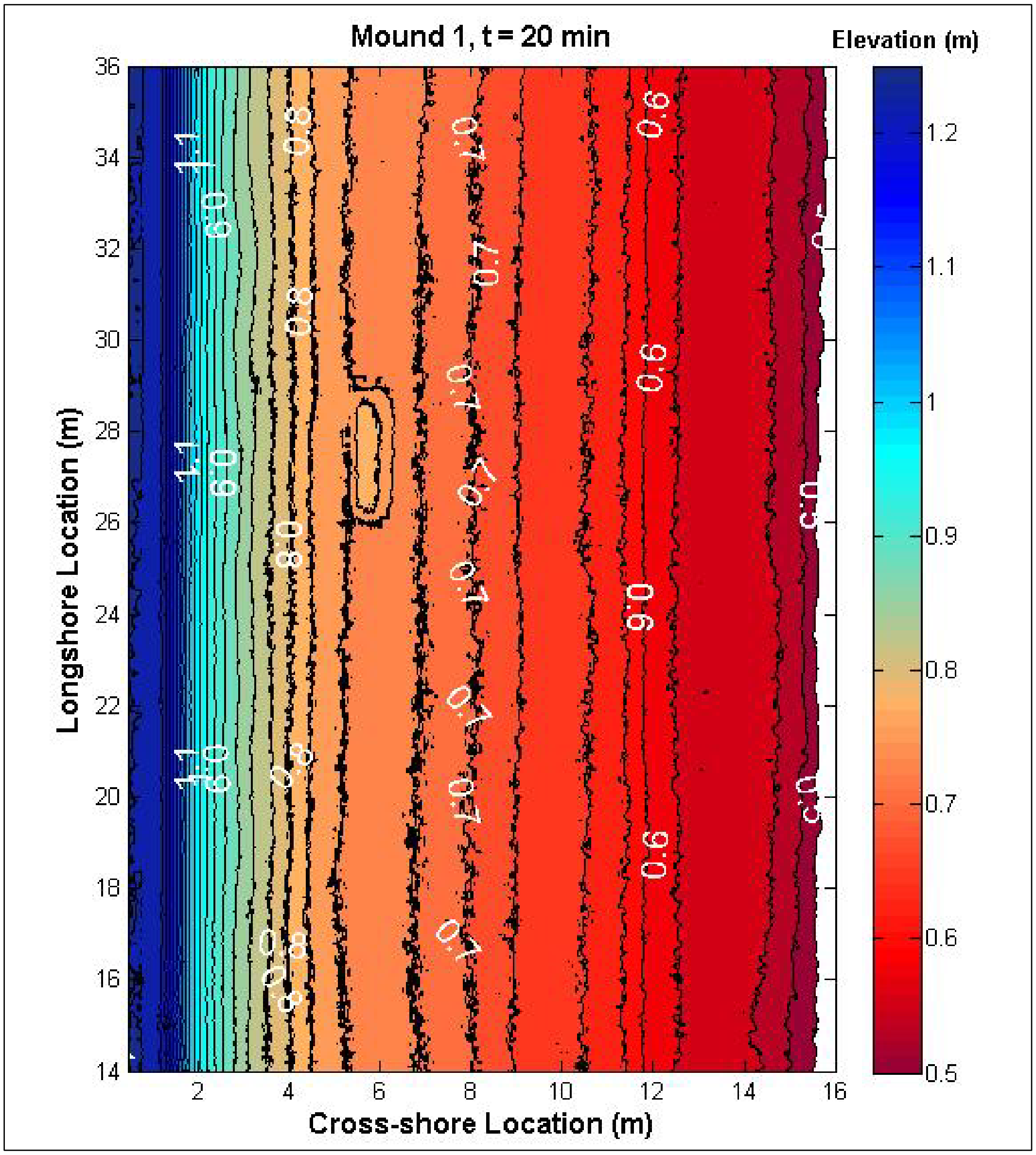


Figure A10. Mound 1 bathymetry after 30 min of waves.

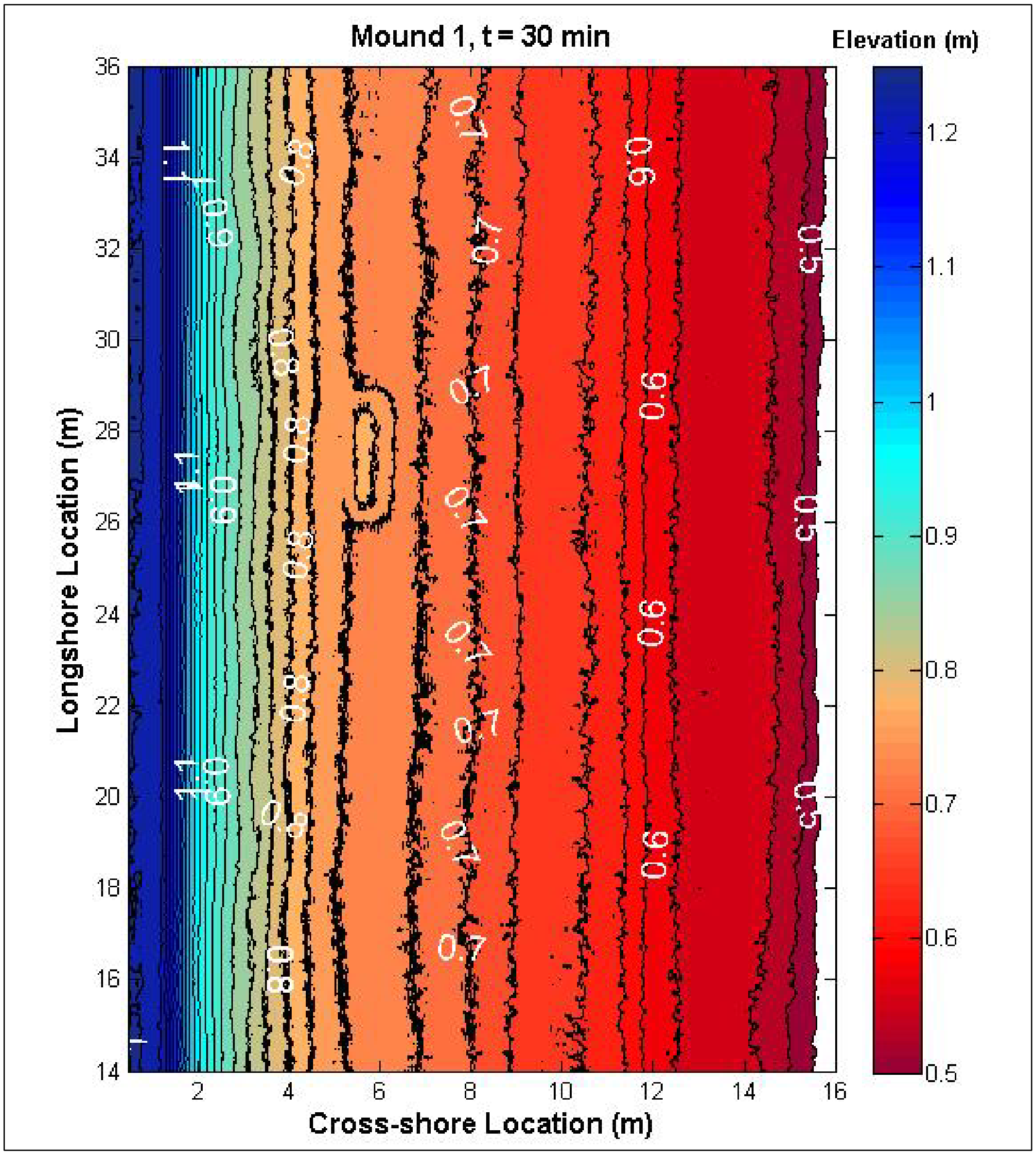


Figure A11. Mound 1 bathymetry after 60 min of waves.

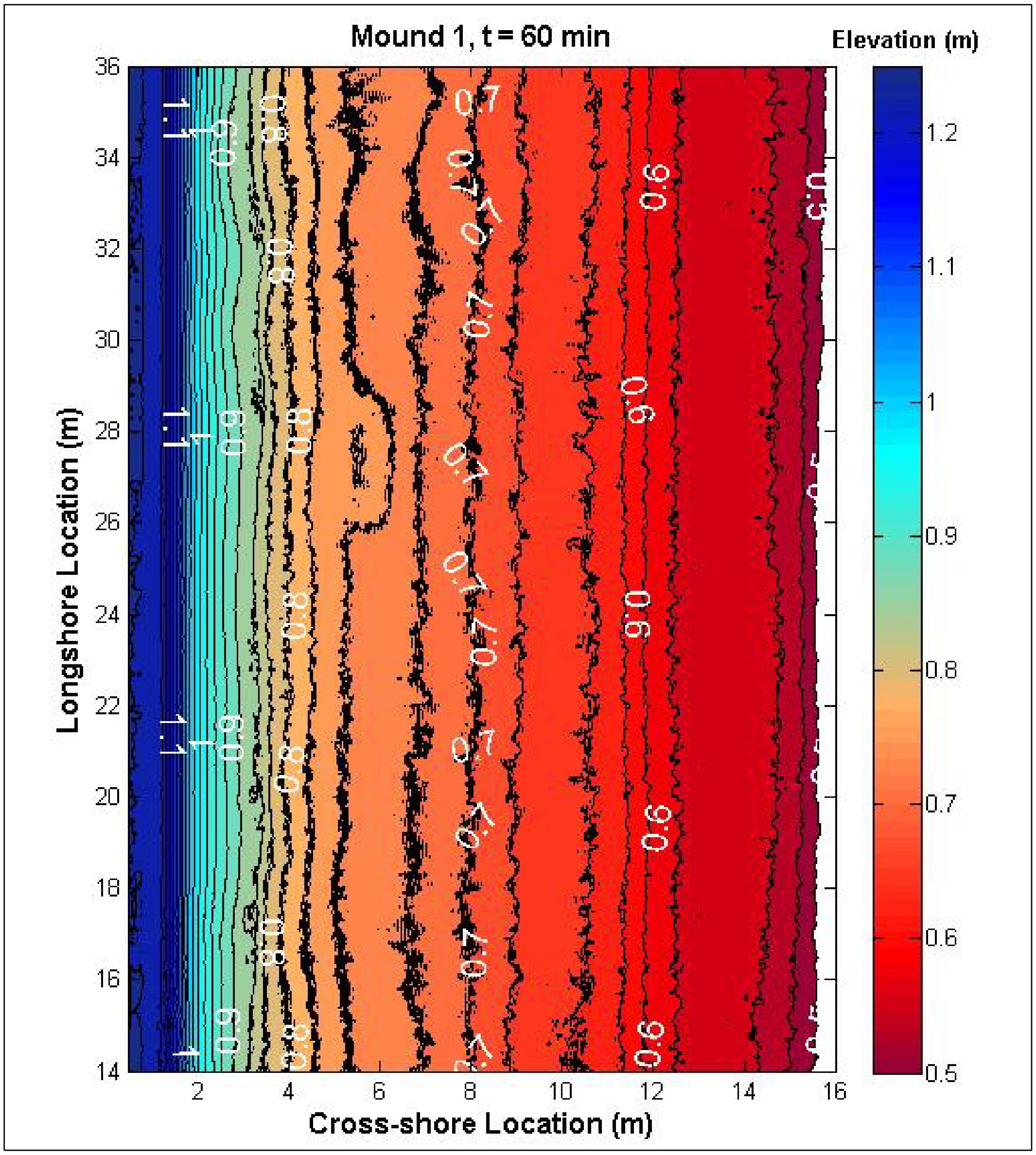


Figure A12. Mound 2 initial bathymetry.

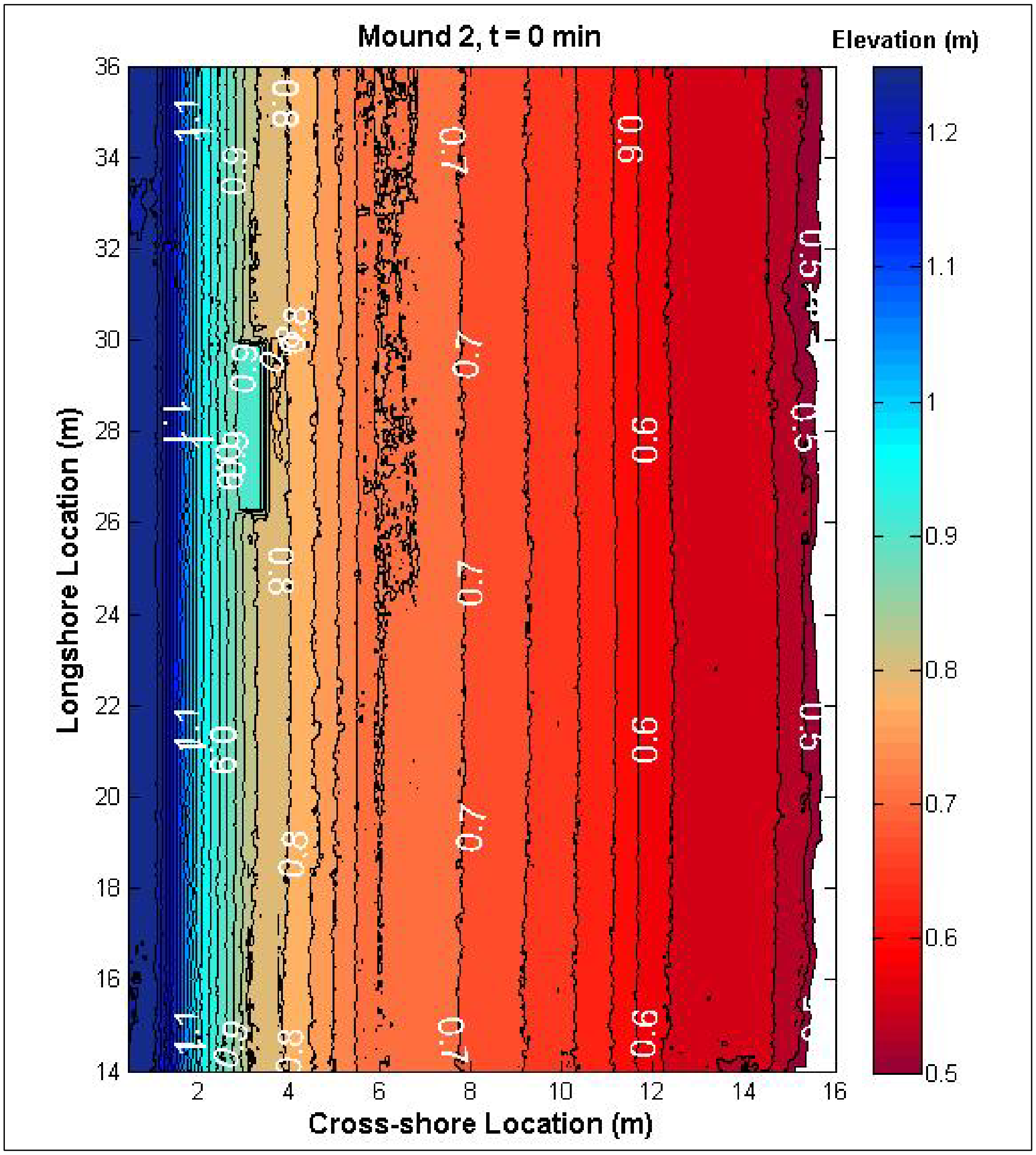


Figure A13. Mound 2 bathymetry after 10 min of waves.

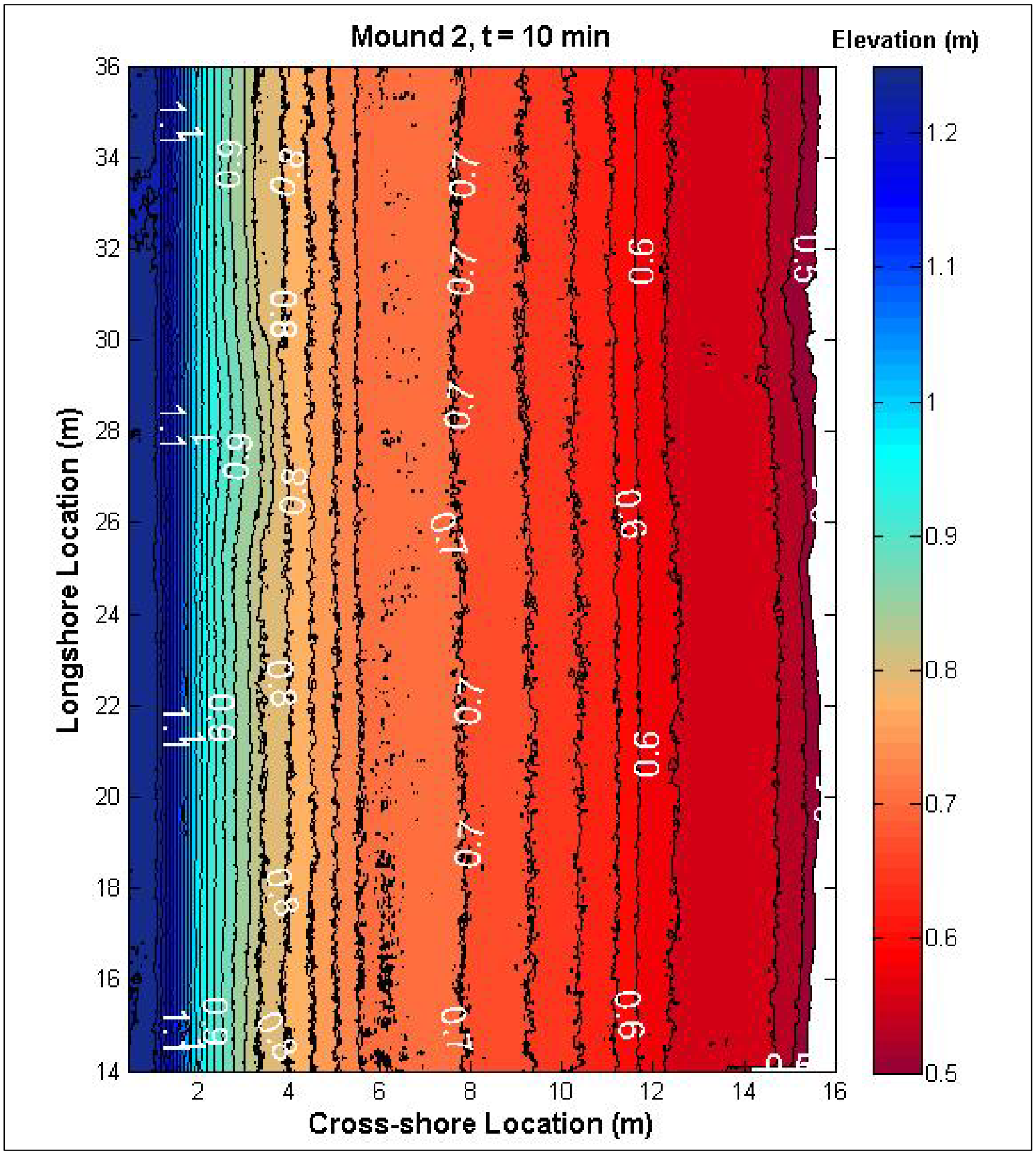


Figure A14. Mound 2 bathymetry after 20 min of waves.

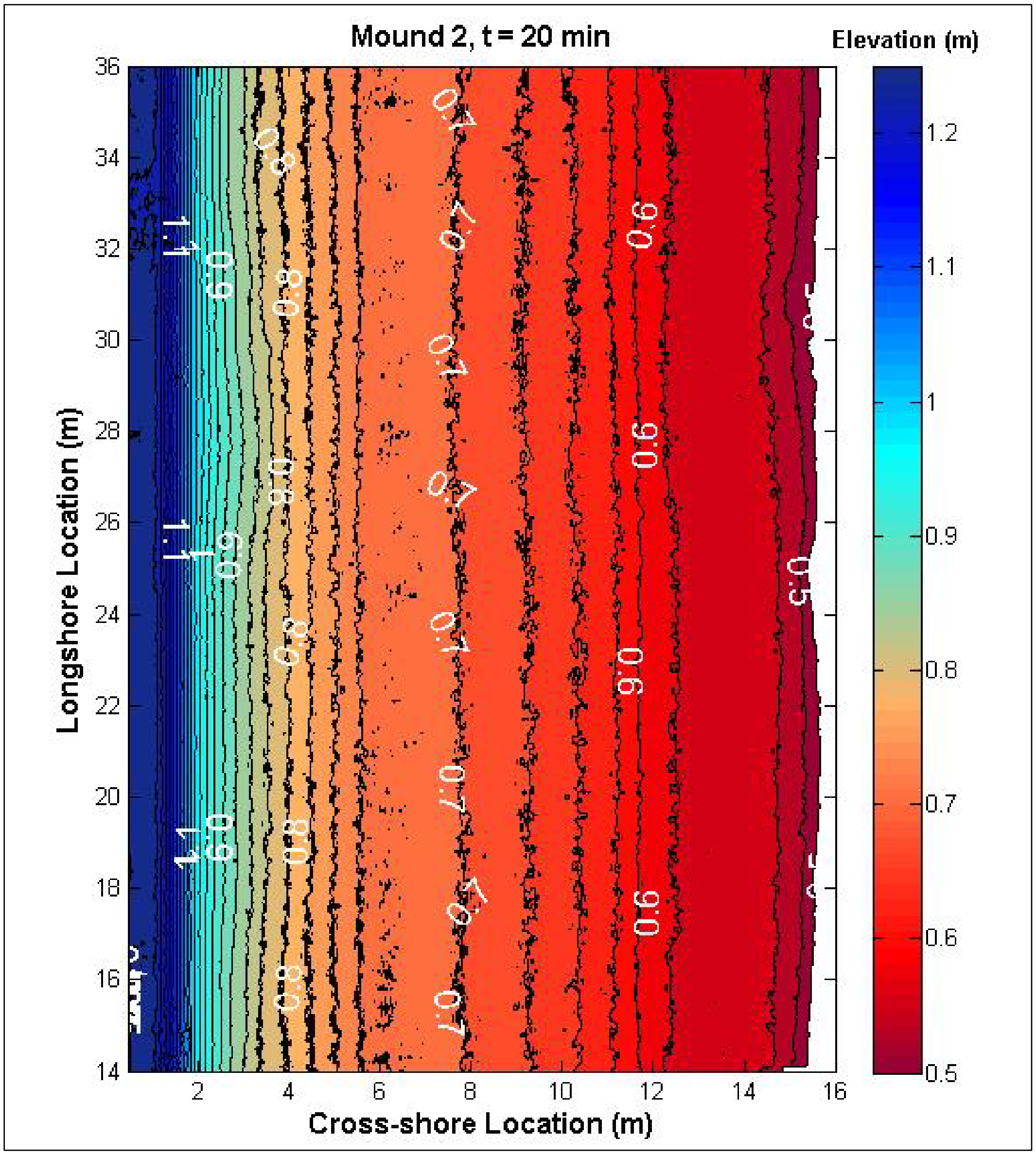


Figure A15. Mound 2 bathymetry after 30 min of waves.

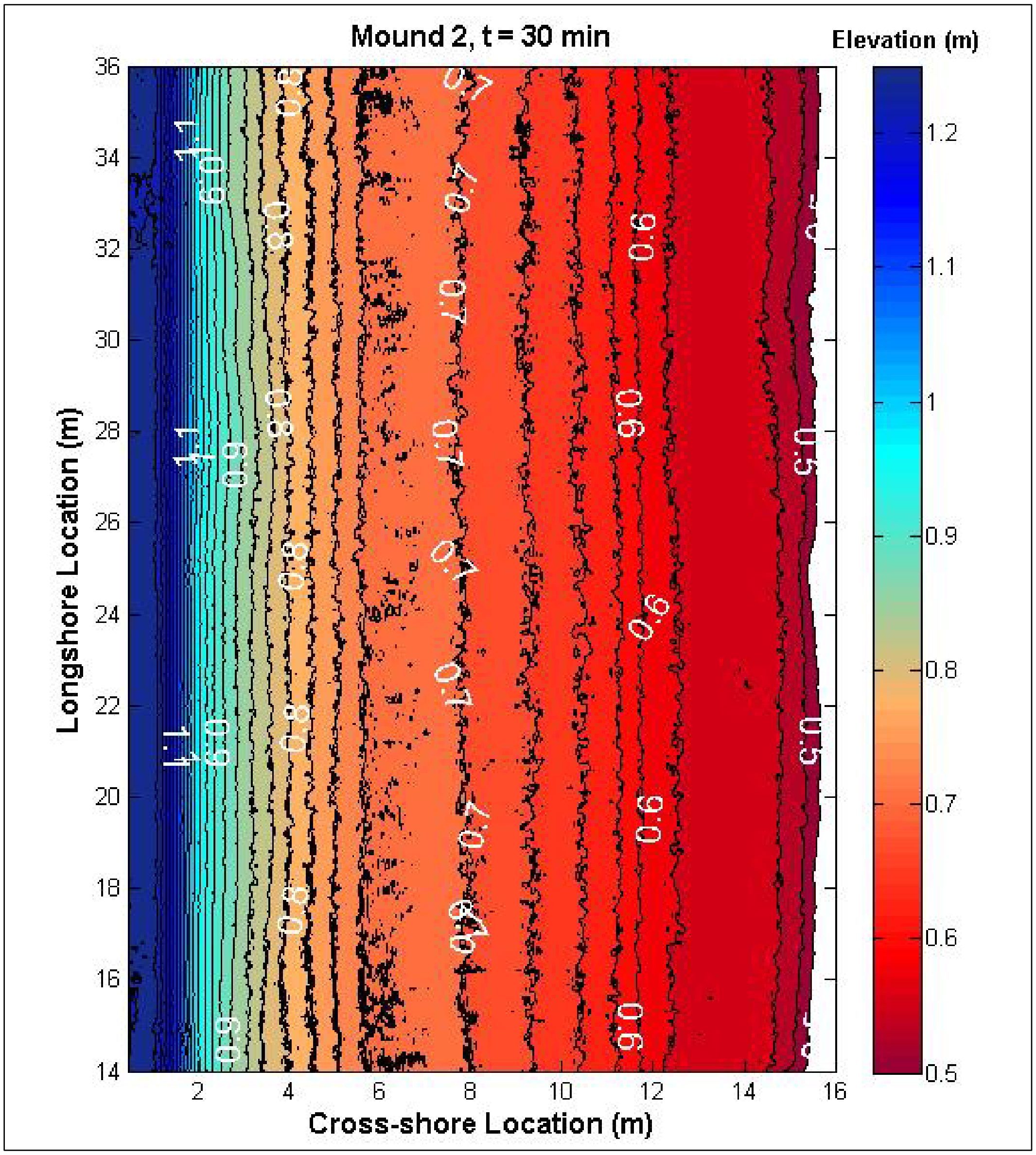


Figure A16. Mound 2 bathymetry after 60 min of waves.

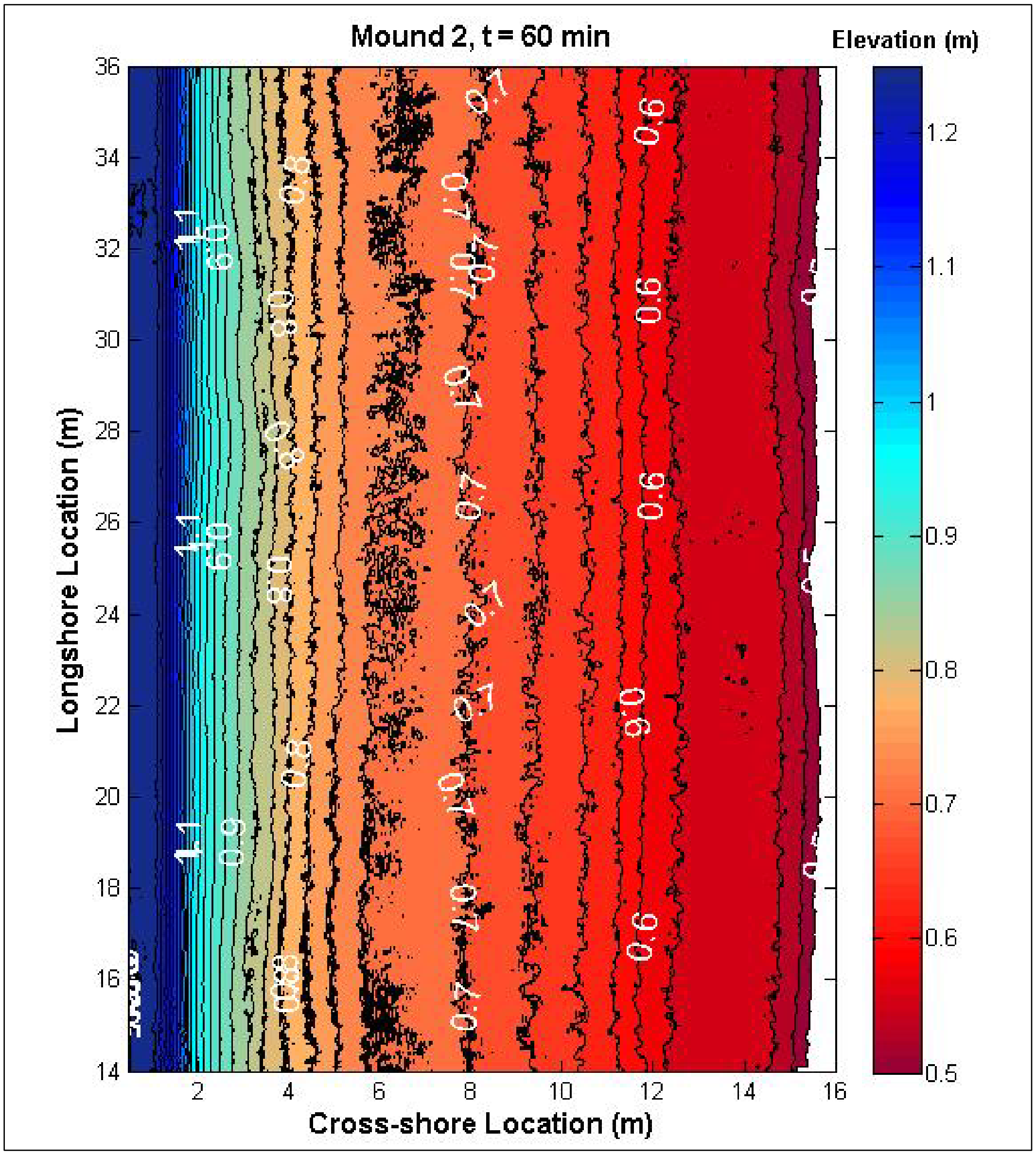


Figure A17. Mound 2 bathymetry after 120 min of waves.

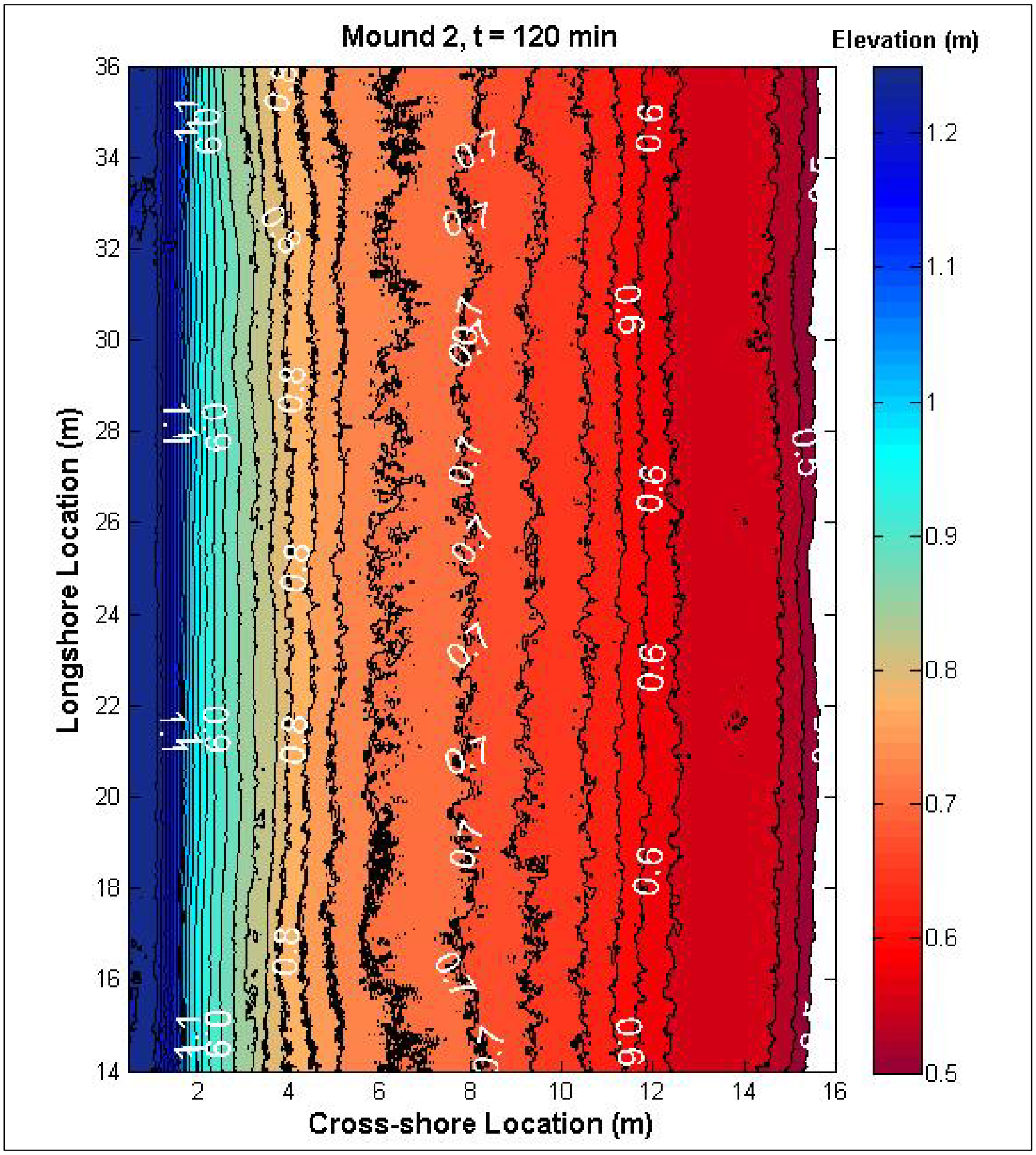


Figure A18. Mound 3 initial bathymetry.

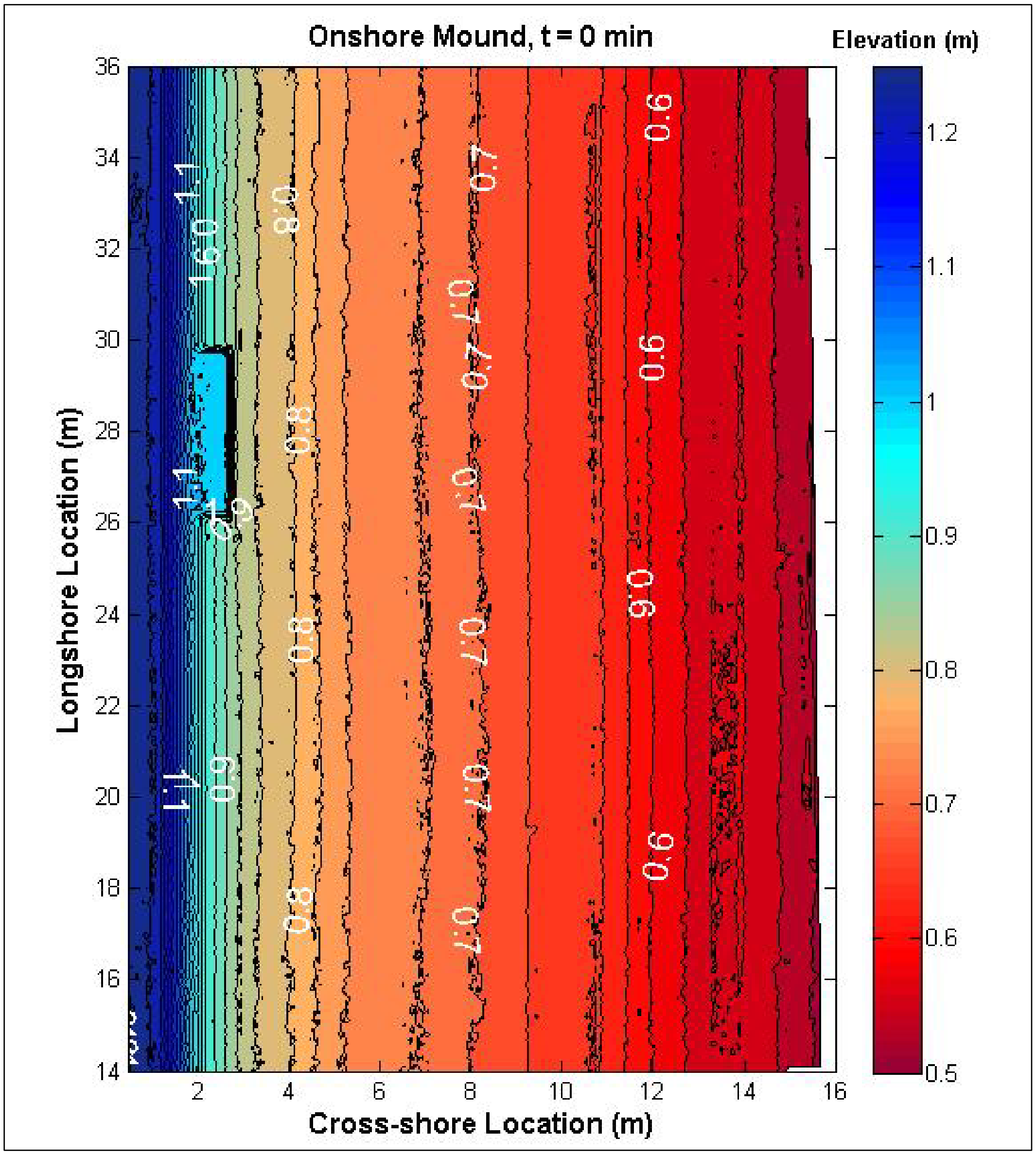


Figure A19. Mound 3 bathymetry after 10 min of waves.

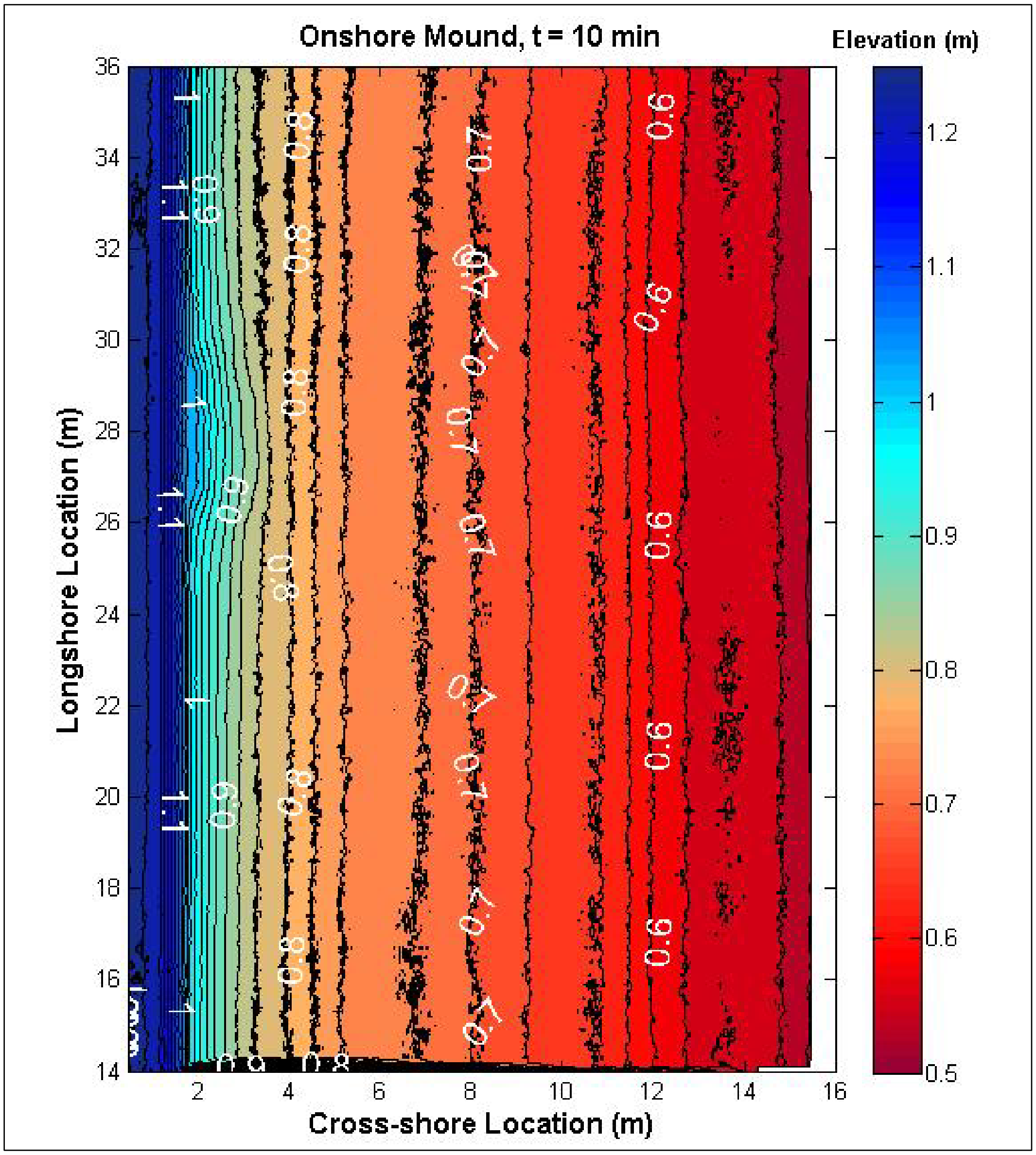


Figure A20. Mound 3 bathymetry after 20 min of waves.

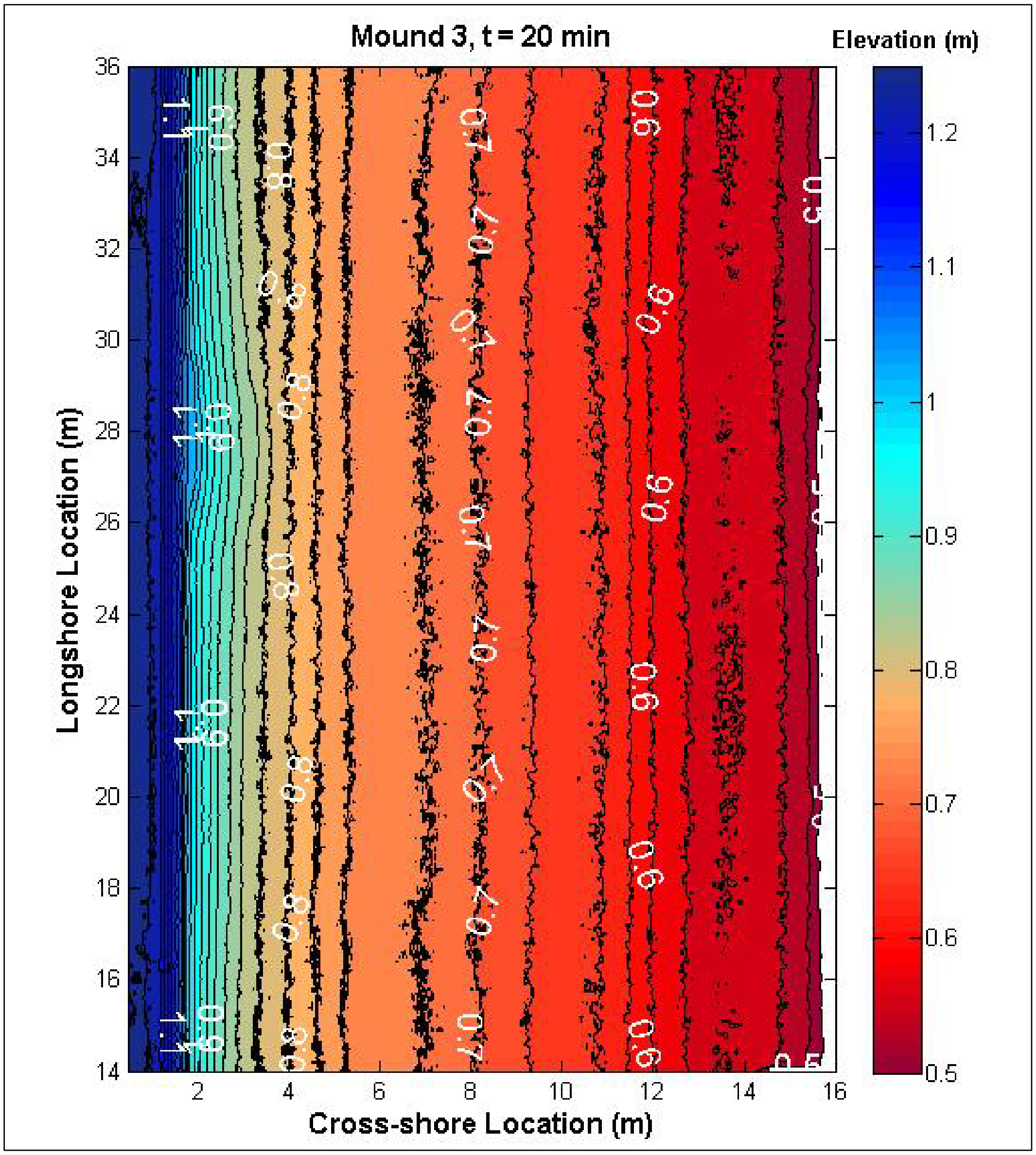
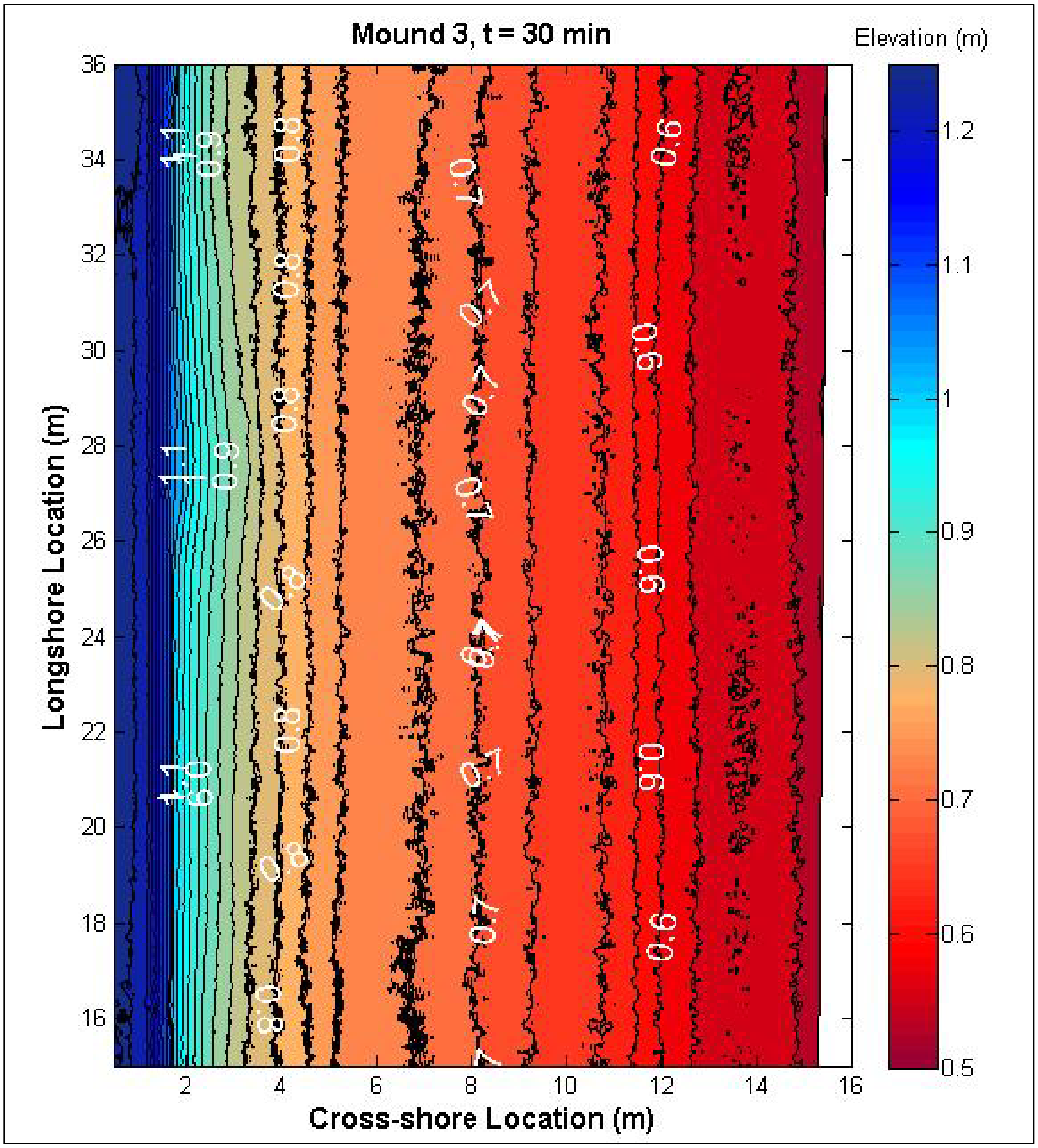


Figure A21. Mound 3 bathymetry after 30 min of waves.



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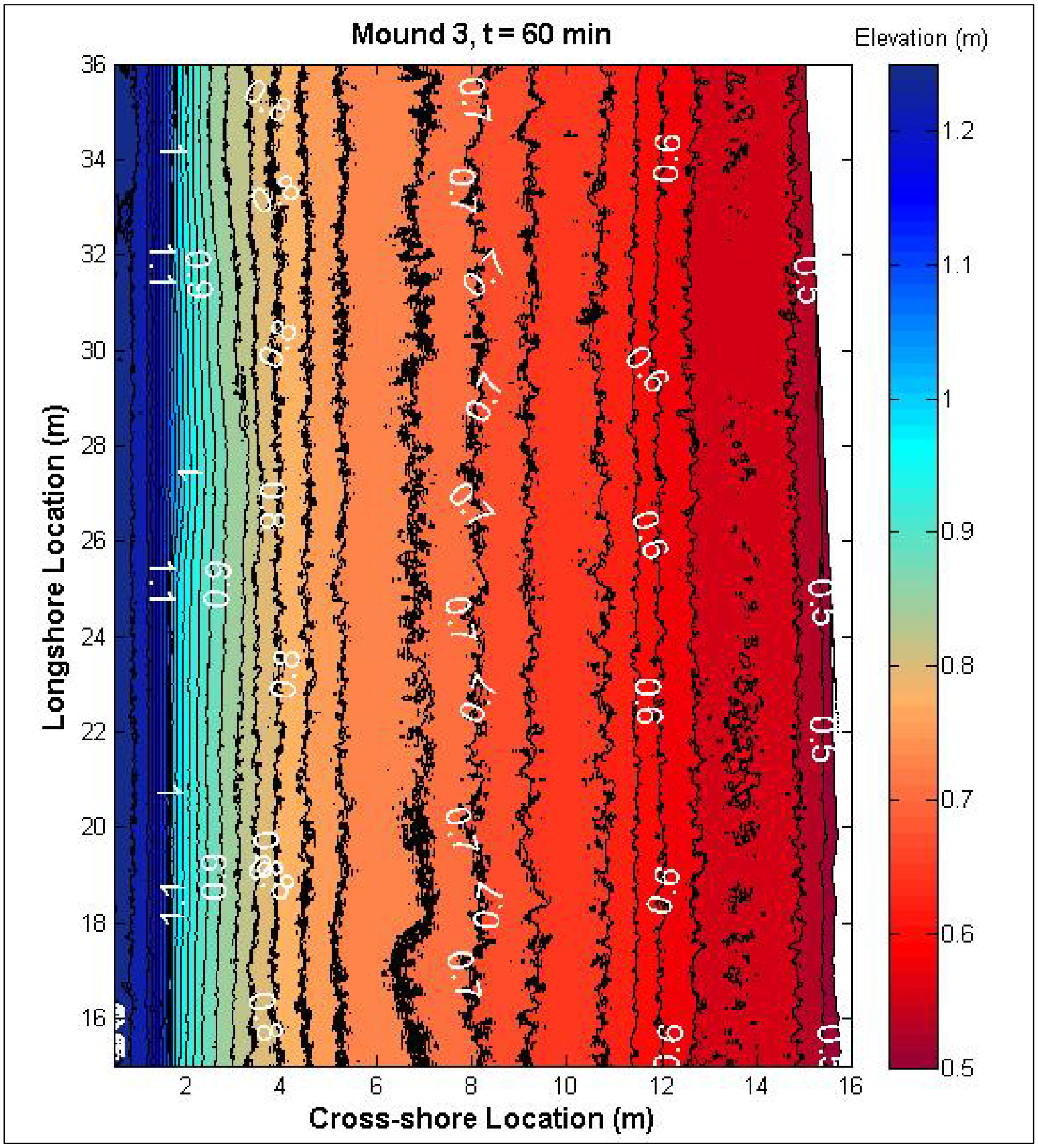
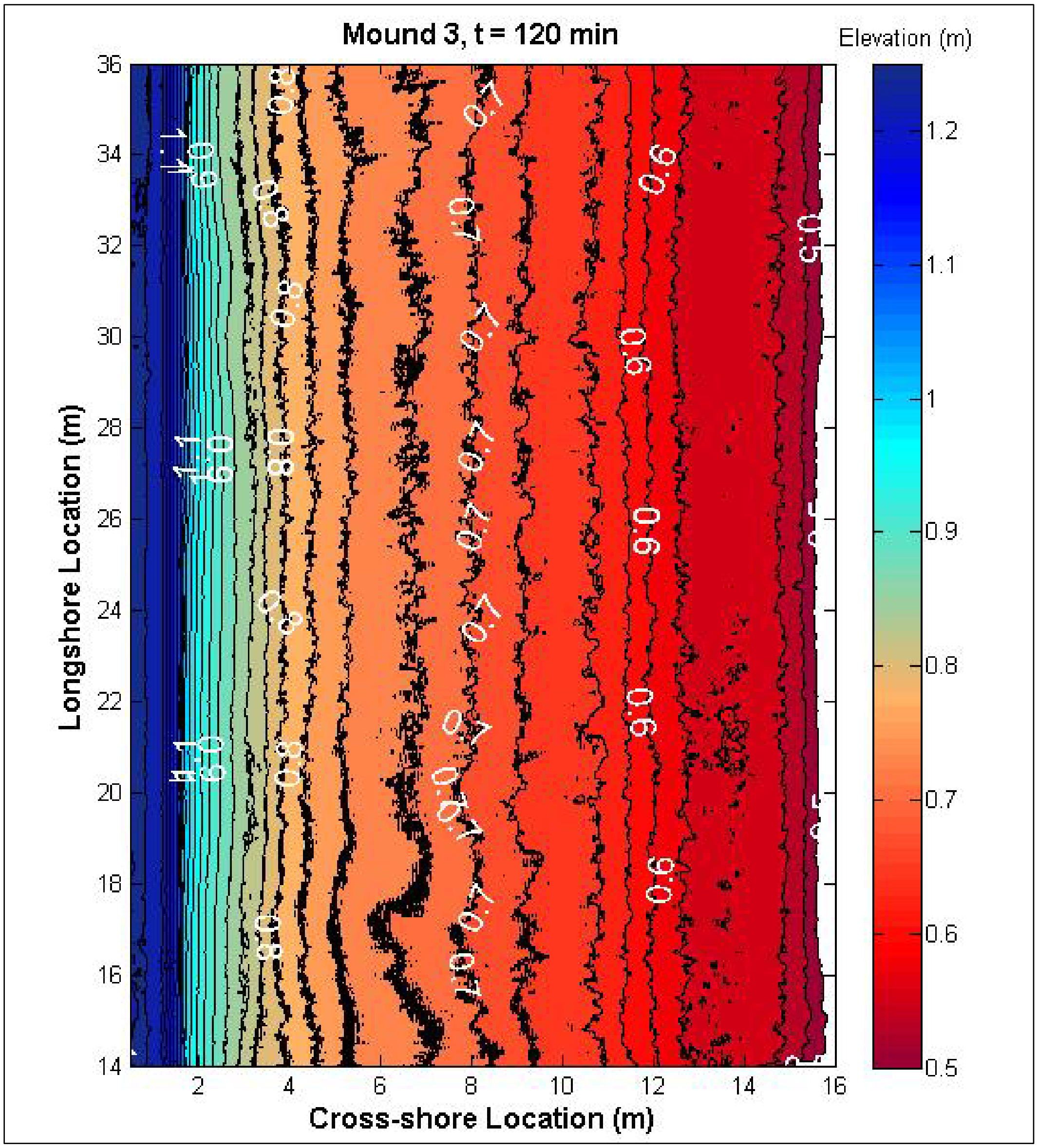


Figure A23. Mound 3 bathymetry after 120 min of waves.



Appendix B: Beach Contour Difference Plots

Change in beach bathymetry between each mound test segment and the initial beach is presented in Appendix B. Beach change comparisons were made by first comparing bathymetries of the mound beach to the base condition beach at common test durations. These differences were then compared to differences between the initial and base condition bathymetries. This method minimized changes that may occur due to the beach profile evolving to equilibrium. In the figures, the offshore direction increases with cross-shore location; waves approach from the right. Longshore transport is directed from higher to lower longshore locations (i.e., from the top to the bottom of the figure). The contours represent elevation differences in centimeters. Positive values indicate areas of accretion compared with the initial beach; negative values reflect areas of erosion.

Figure B1. Mound 1 relative bathymetry difference after 10 min of waves.

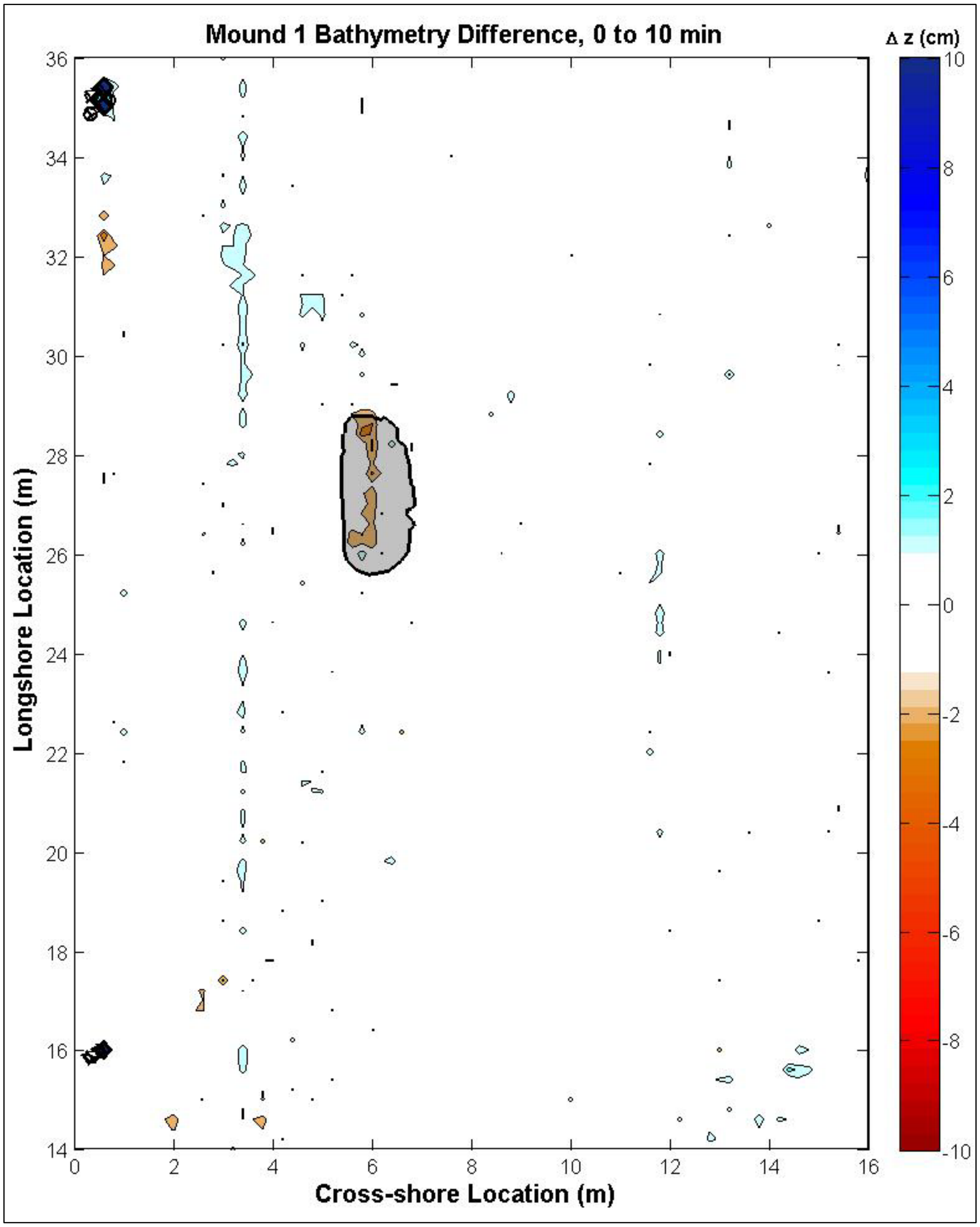


Figure B2. Mound 1 relative bathymetry difference after 20 min of waves.

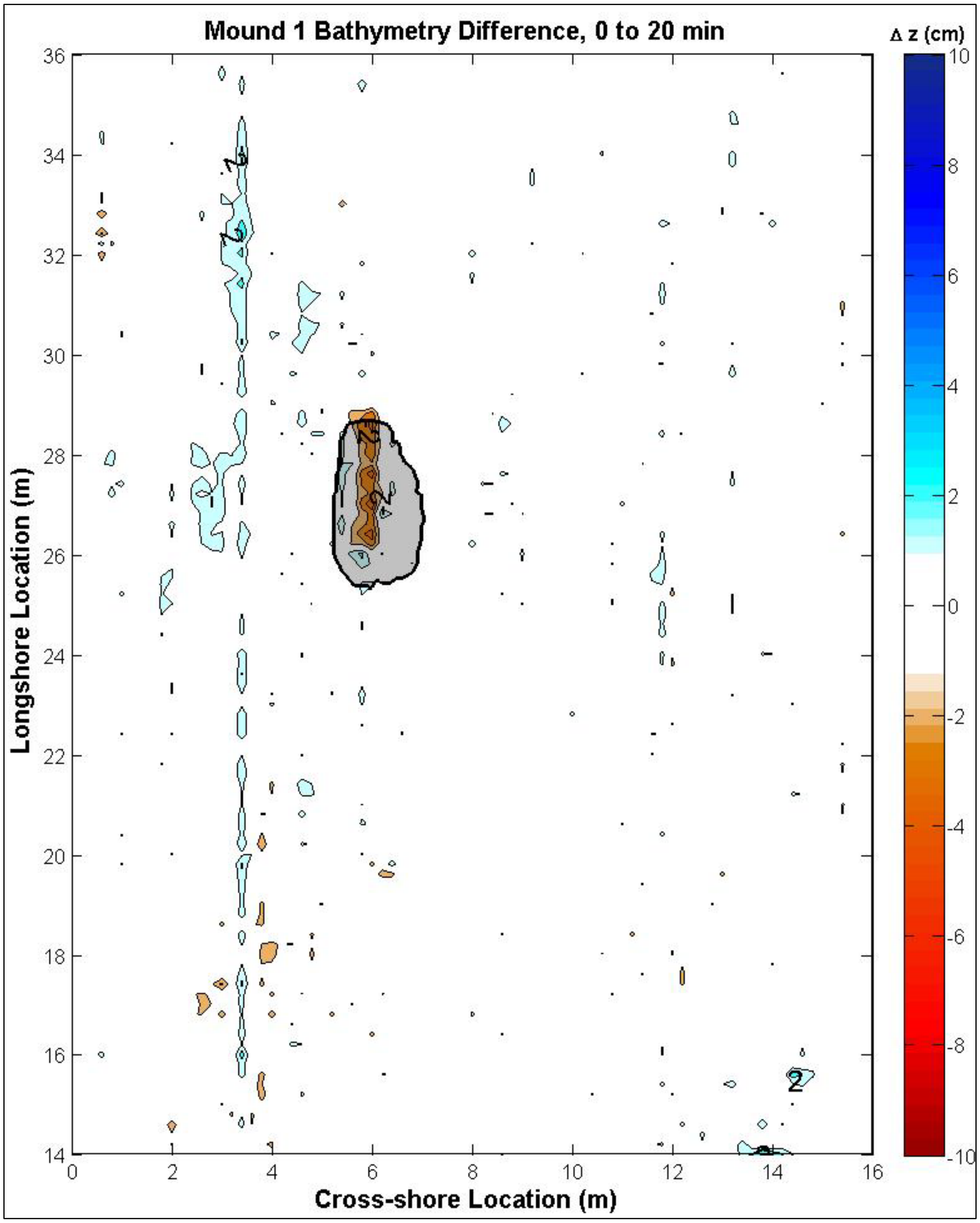


Figure B3. Mound 1 relative bathymetry difference after 30 min of waves.

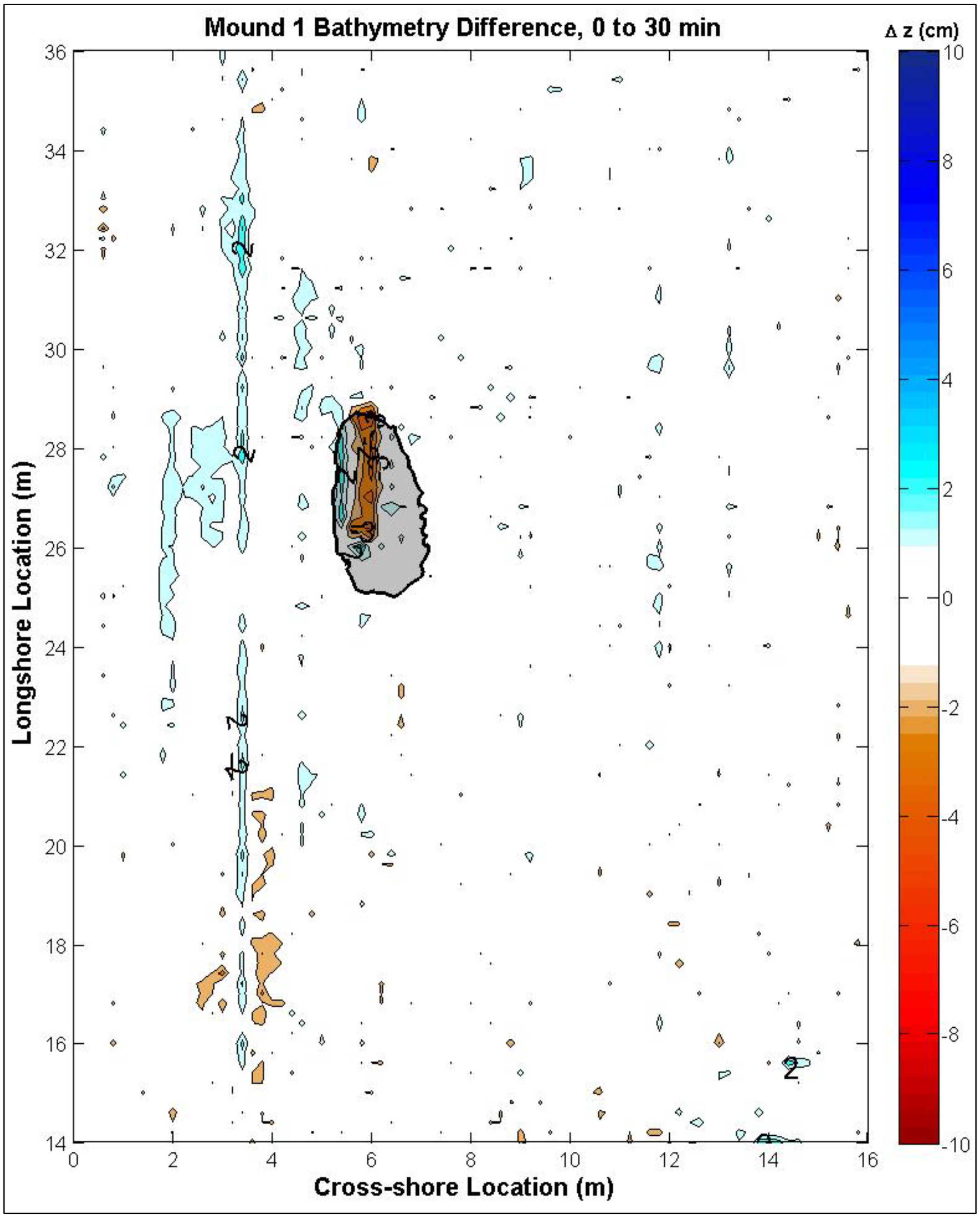


Figure B4. Mound 1 relative bathymetry difference after 60 min of waves.

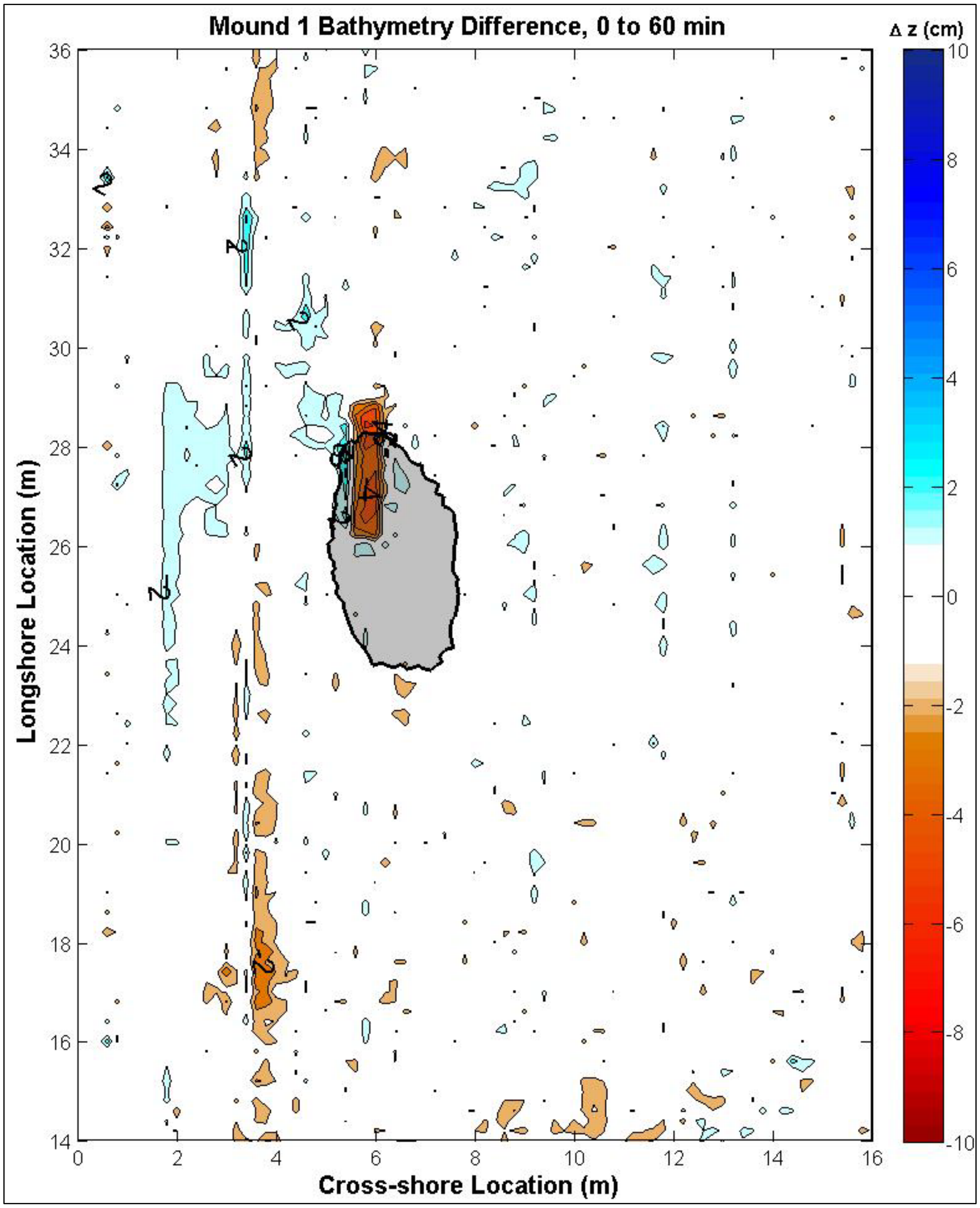


Figure B5. Mound 2 relative bathymetry difference after 10 min of waves.

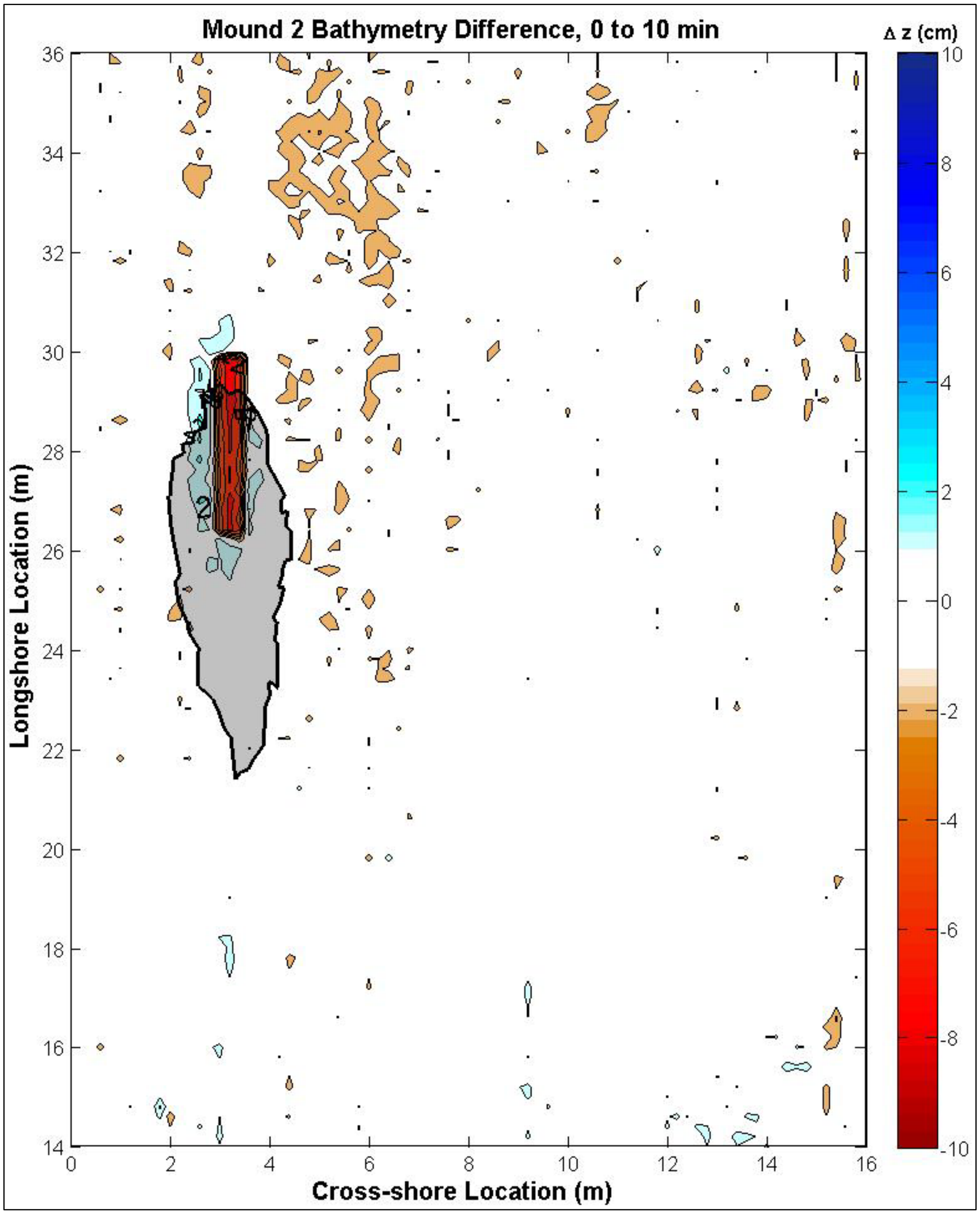


Figure B6. Mound 2 relative bathymetry difference after 20 min of waves.

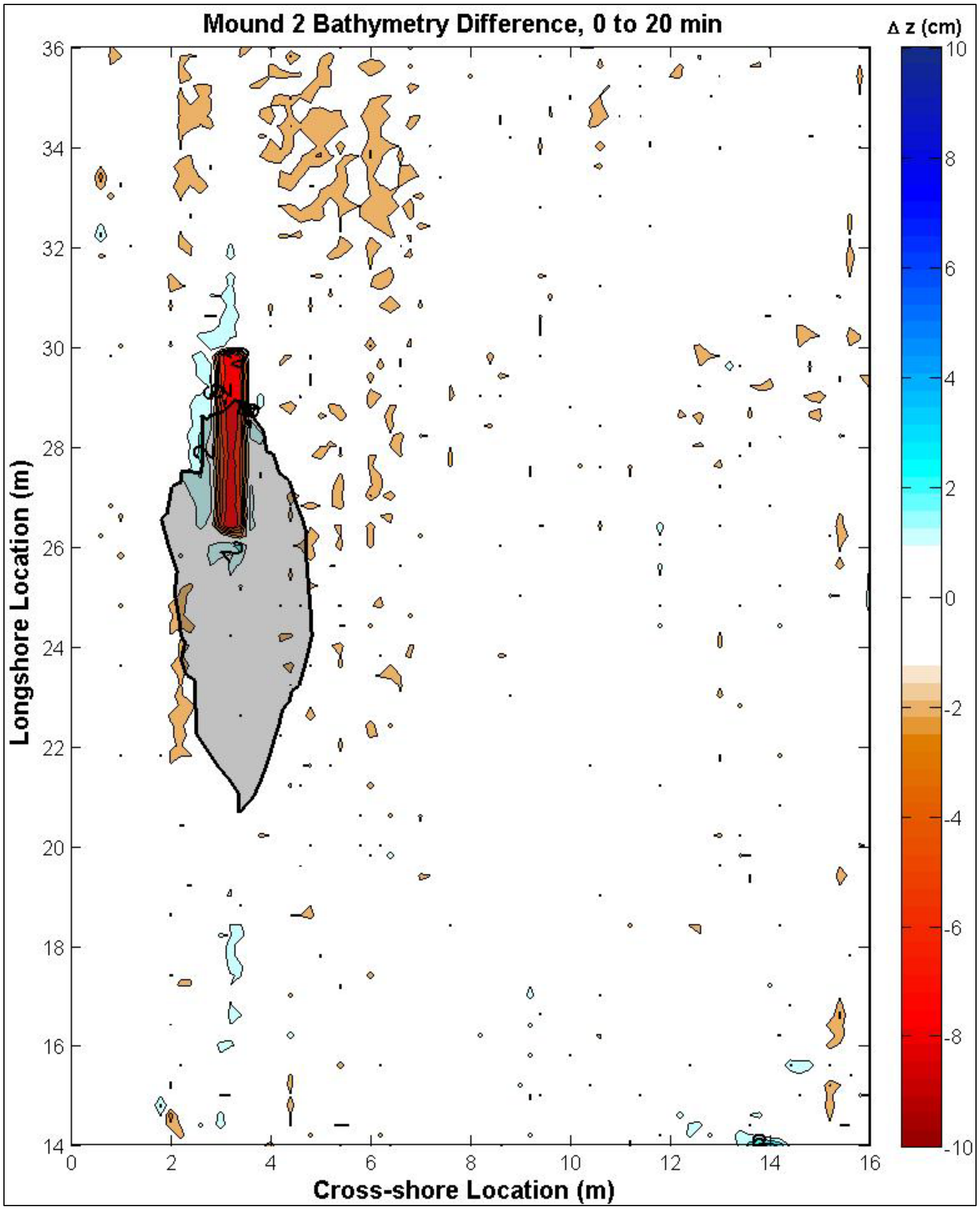


Figure B7. Mound 2 relative bathymetry difference after 30 min of waves.

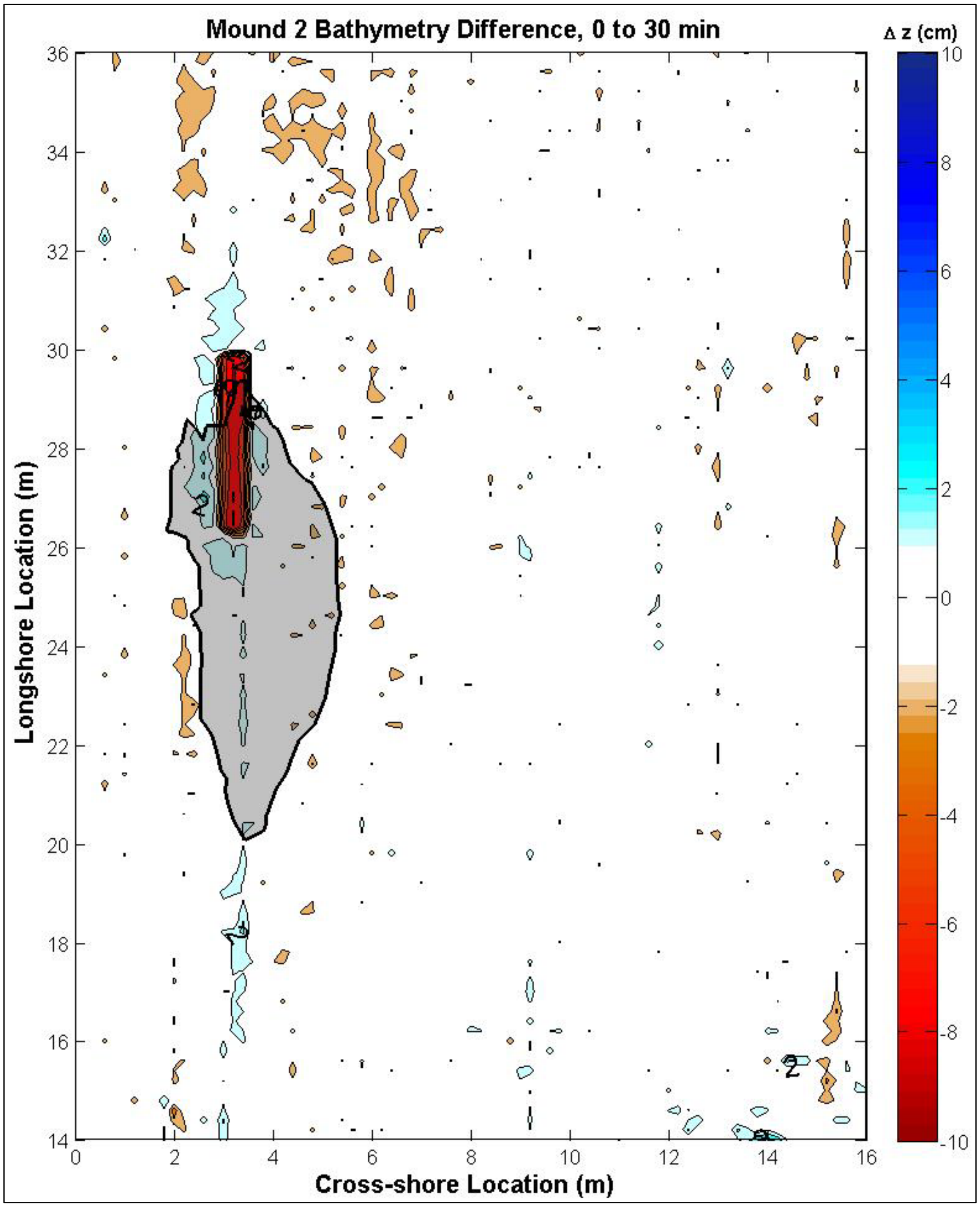


Figure B8. Mound 2 relative bathymetry difference after 60 min of waves.

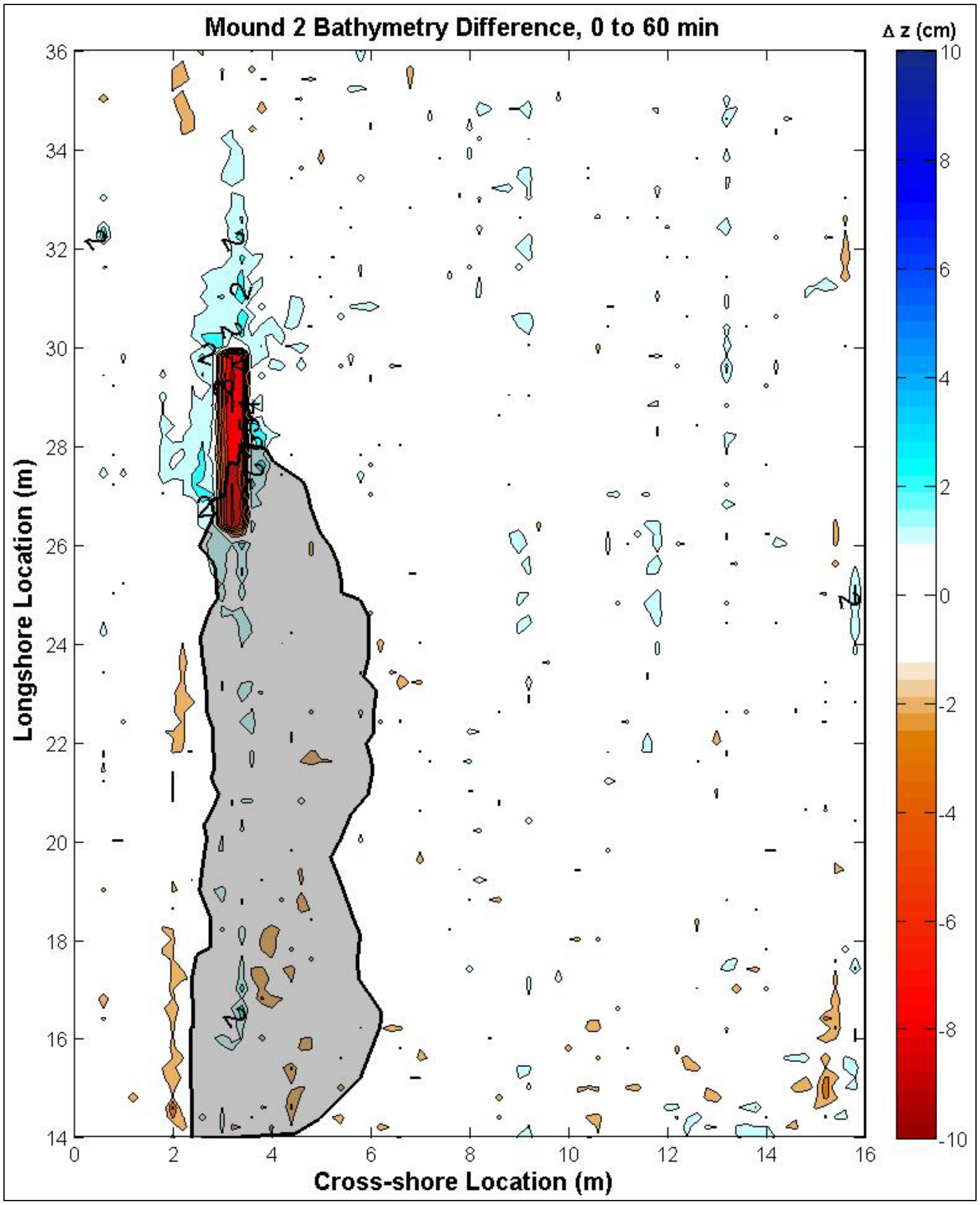


Figure B9. Mound 2 relative bathymetry difference after 120 min of waves.

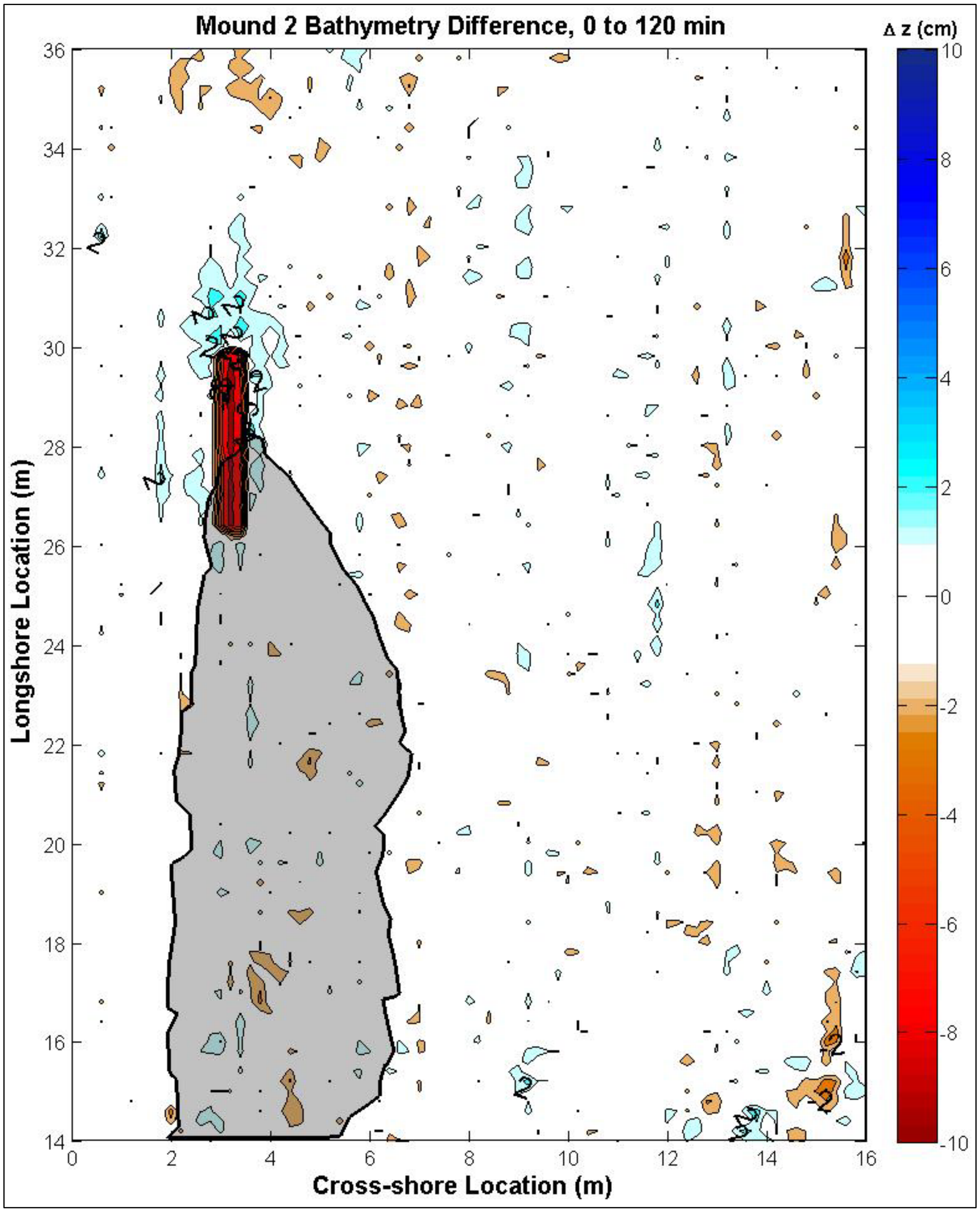


Figure B10. Mound 3 relative bathymetry difference after 10 min of waves.

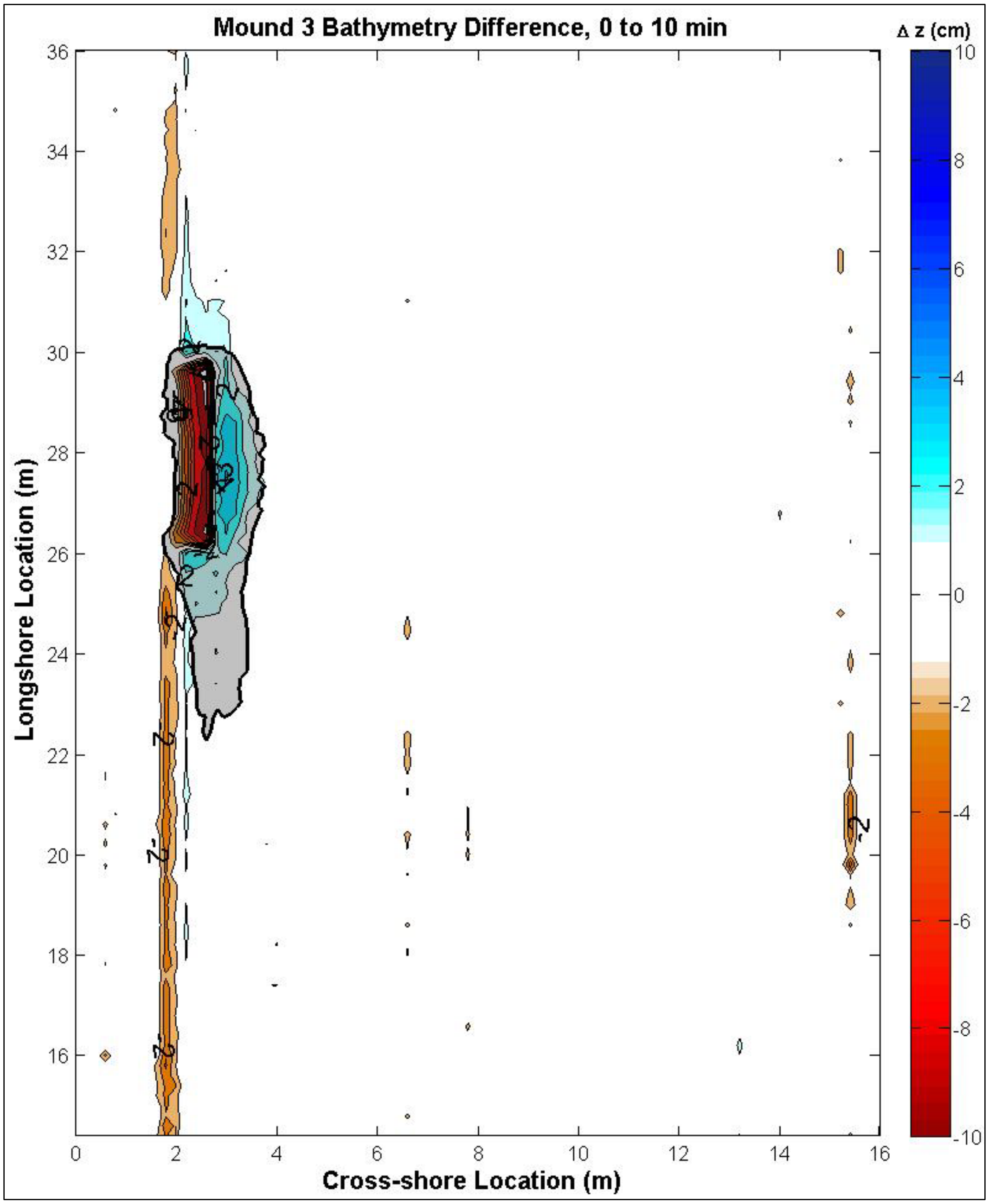


Figure B11. Mound 3 relative bathymetry difference after 20 min of waves.

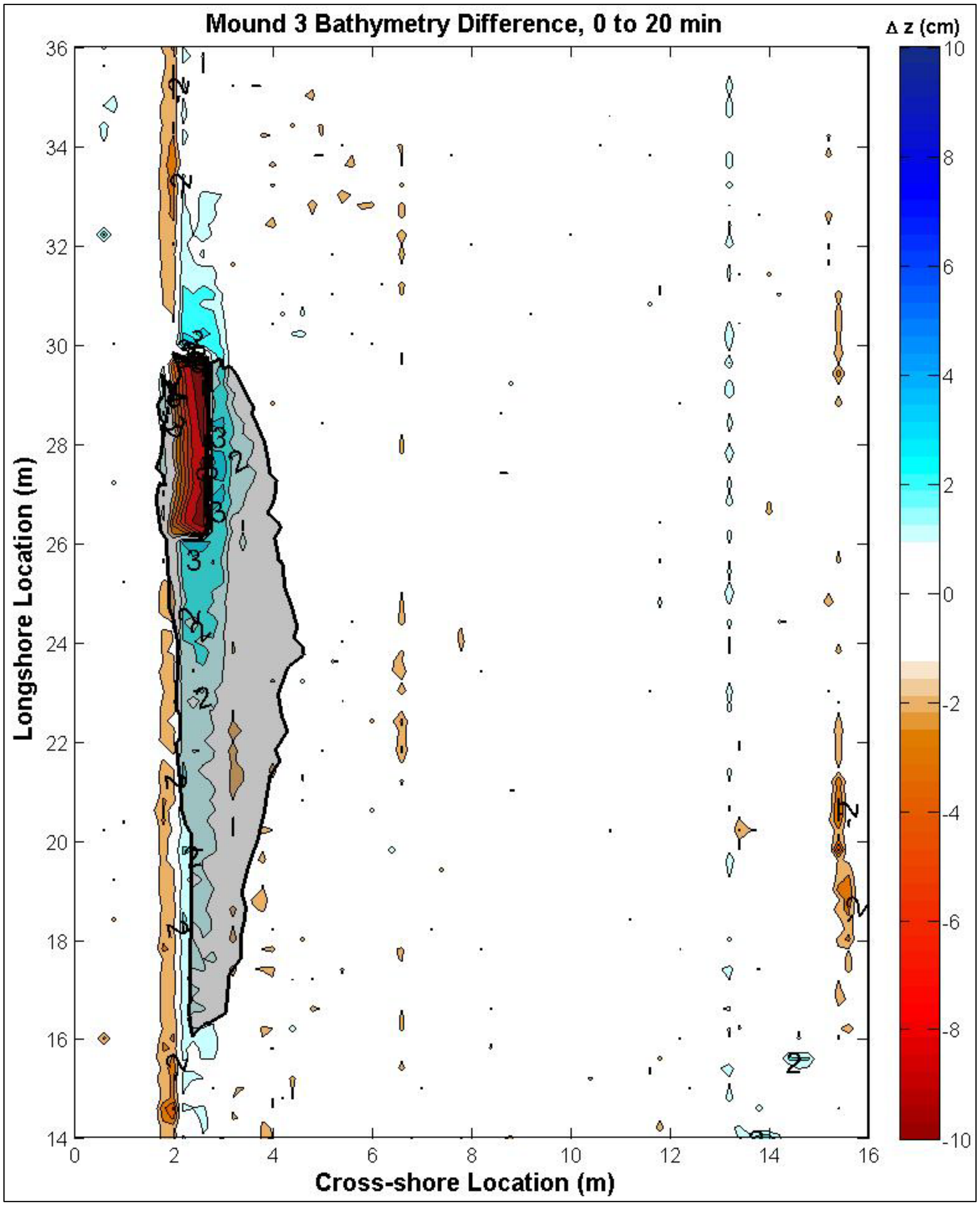


Figure B12. Mound 3 relative bathymetry difference after 30 min of waves.

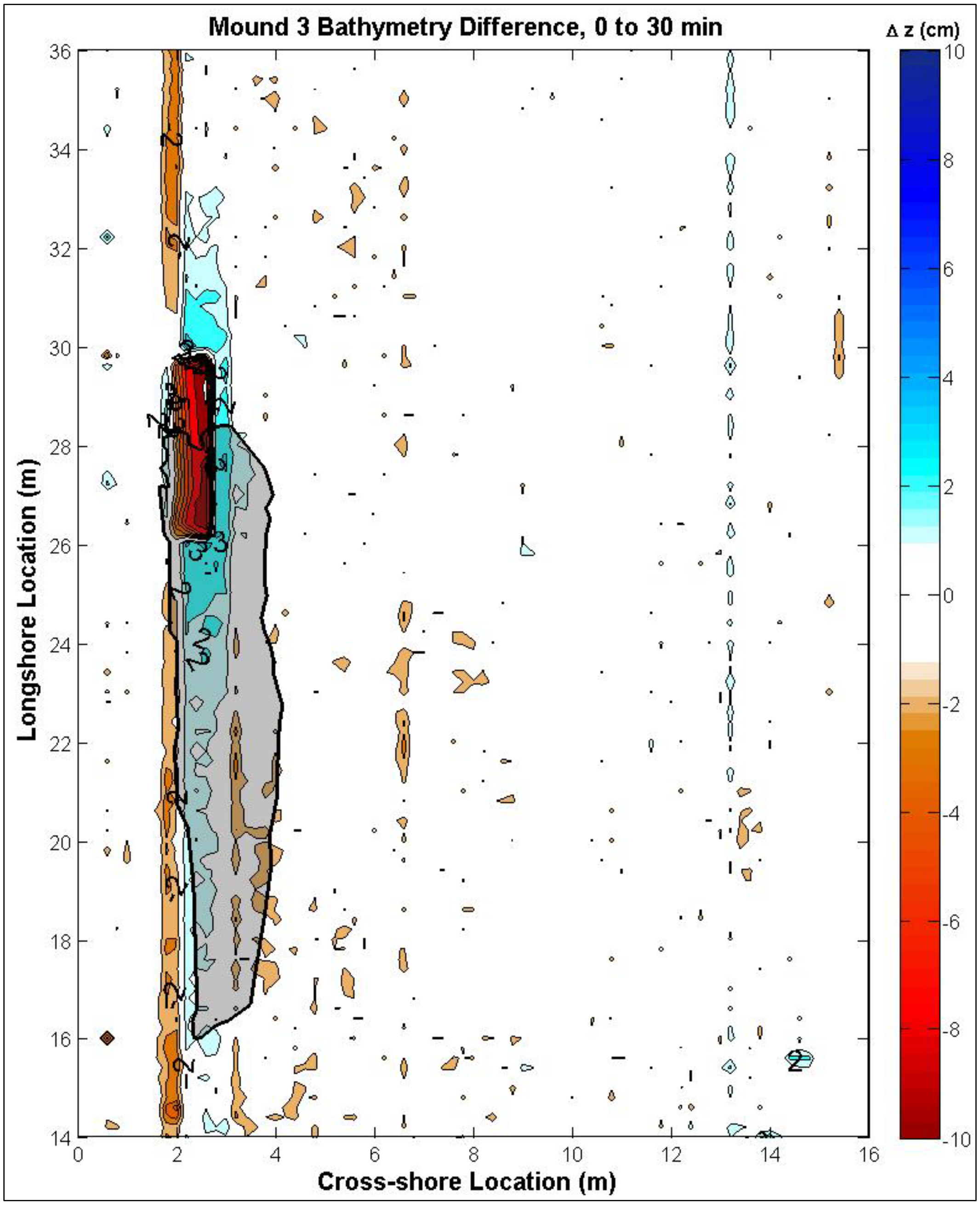


Figure B13. Mound 3 relative bathymetry difference after 60 min of waves.

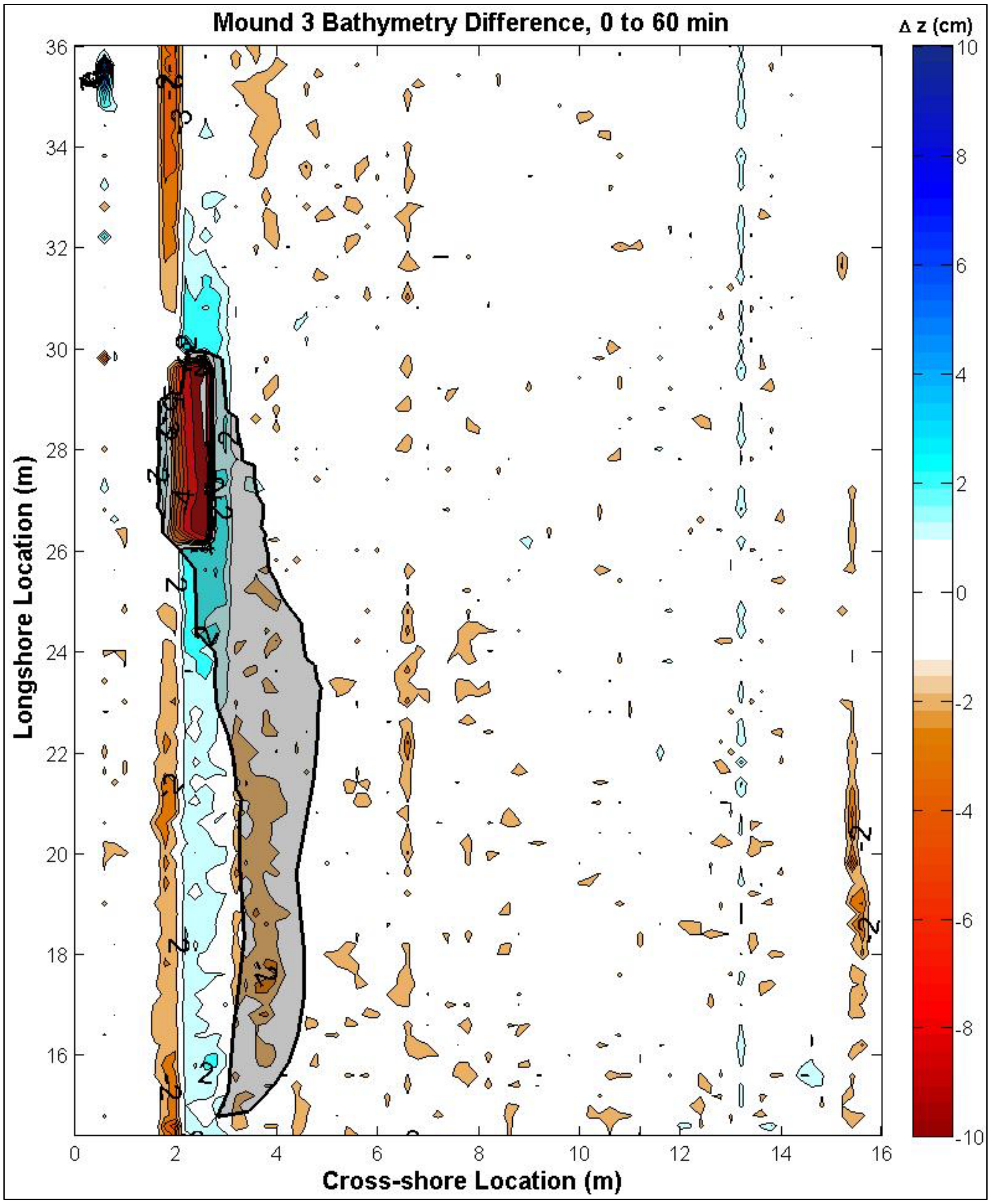
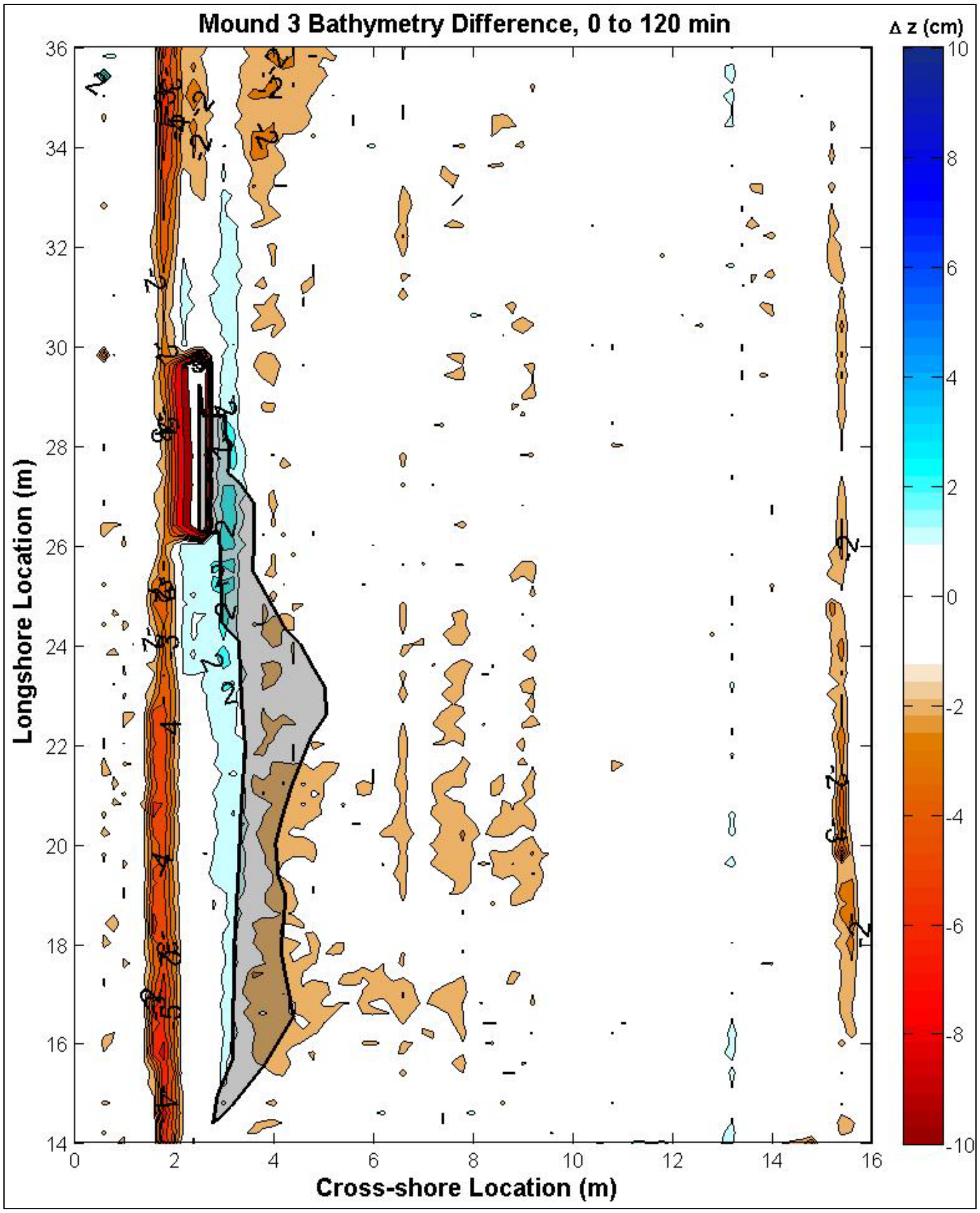


Figure B14. Mound 3 relative bathymetry difference after 120 min of waves.



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13. SUPPLEMENTARY NOTES

14. ABSTRACT

Movable-bed, large-scale laboratory experiments were conducted at a 1:20 scale to examine the fate and quantify the performance of nearshore-placed dredged material as subaerial and submerged mounds or berms. Three tests were performed for mounds placed at depths representing 1.2 and 3.35 meters and placement onshore. Mound sand was dyed to provide contrast and to differentiate it from the natural sand beach used in the model. Beach surveys were performed intermittently during each 9-hour (prototype) experiment with a laser scanner. In addition to beach change elevations, the scanner provided RGB color components, which enabled tracking of the mound sand. Mound sand dispersed rapidly and was transported mainly downdrift. However, no evidence of appreciable accretion was observed downdrift of the mounds placed offshore. Although the mound sand was transported downdrift, sand accumulation was observed on the beach onshore and updrift of the mounds. Beach response was similar to that of an offshore breakwater in which the mound provides a wave shadow zone to the leeward beach. The mound placed on the foreshore slope accreted in the swash zone directly downdrift of the mound and near the shoreline over the beach length. The experiment demonstrated that nearshore-placed material remains in the surf zone and adds material to the beach face.

15. SUBJECT TERMS

Beneficial uses	Dredged material	Wave breaking
Longshore currents	Longshore sediment transport	Large-scale Sediment Transport Facility
Physical modeling	Surf zone processes	Nearshore-placed mounds
	Image processing	Wave transformation
	Movable-bed modeling	

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